Alexander Ziwet

The Harnessing of Niagara

THE CASSIER MAGAZINE CO.
New York and London
1895

PREFACE.

RECOGNIZING the great interest which the world is showing in the work at Niagara Falls, by which it is proposed eventually to obtain the enormous quantity of 450,000 horse-power, to be distributed electrically hundreds of miles away, the publishers of CASSIER'S MAGAZINE arranged with the eminent engineers and electricians in charge of the work, to supply them with the first complete and authentic account of this, the greatest engineering feat of the century, from its inception to the application of the current for commercial purposes. The result was a magazine of unusual size and without doubt the most important engineering publication ever issued, clearly destined to be an enduring work of reference on the subject. A more substantial binding than the conventional paper cover therefore suggested itself for the number, for library use, and led to the issuing of the magazine in the present shape, in which it will commend itself, even more than before, to every one interested in the remarkable enterprise at Niagara Falls.

THE CASSIER MAGAZINE CO.

NEW YORK AND LONDON.

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THE CENTRAL HALL OF THE MACHINE SHOP OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, PITTSBURGH, PA.

A complete story
of the
great Niagara power enterprise,
comprised in ten articles,
with nearly two hundred illustrations,
including portraits of the officers and
directors of the Cataract Construction Company,
the members of the
International Niagara Falls Commission,
and
the engineers under whose
supervision the work
was carried out.

To drive "the roaring loom of Time itself."—JAMES RUSSELL LOWELL.

Edward D. Adams

Charles F. Clark

JOHN JACOB ASTOR.

GEORGE S. BOWDOIN.

Charles Lanier

D. O. Mills

Wm. B. Rankine

F. W. Whitridge

Edward A Watkins

F. L. Stetson

Francis Lynde Stetson is the first vice-president of the Cataract Construction Company, and, as such, is among the best qualified to present a general and comprehensive account of the use of Niagara water power.

Niagara Number.

CASSIER'S MAGAZINE.

VOL. VIII. JULY, 1895. NO. 3.

THE HORSESHOE FALLS.

THE USE OF THE NIAGARA WATER POWER.

By Francis Lynde Stetson.

SINCE Father Rageneau, in 1648, wrote to his Father Superior concerning Niagara, "a cataract of fearful height," spectators by the million unconsciously have revealed something of themselves in various efforts to disclose to others the essential character of the Falls of Niagara, confessedly incomparable with any other natural object. To souls sensitive to the beautiful and the sublime, the plunging torrent has appealed by the stateliness of its stream, the brilliance of its boisterous rapids, and the deep glassy green of its silent foreboding brink, as well as by its drop into the seemingly infinite depth, from which there comes to him who listens the note of the welcoming abyss, deeper than the diapason of any organ's pipe.

To most, the first impression, and to many the enduring impression, is that of awe, in which the subjective mood prevails and a certain sense of personal danger dominates all other thoughts of this mighty moving flood, pouring resistlessly down through the gorge, which, for itself, it has forced through multiplied strata of rocks of many ages. Danger there certainly is, and death in this resistless, remorseless tide has been

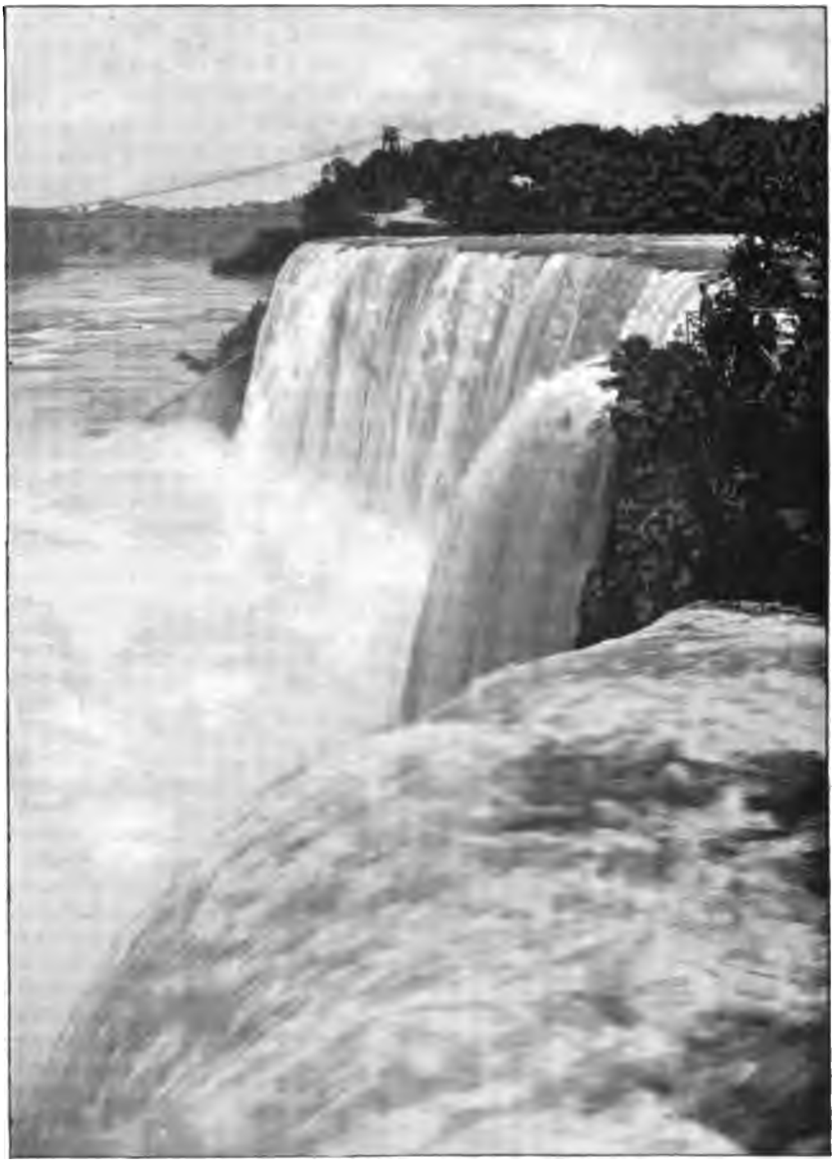
THE FALLS FROM PROSPECT POINT.

found and also has been sought by hundreds; but notwithstanding its appalling aspect, it is through this very sense of resistless power that the Falls speak to minds of great dignity and self-restraint, and lead them to observe as did Mr. Carter of New York, in his characteristically fine oration at the opening of Niagara Park, that the "sense which responds to this magnificent motion" is the "sense of power."

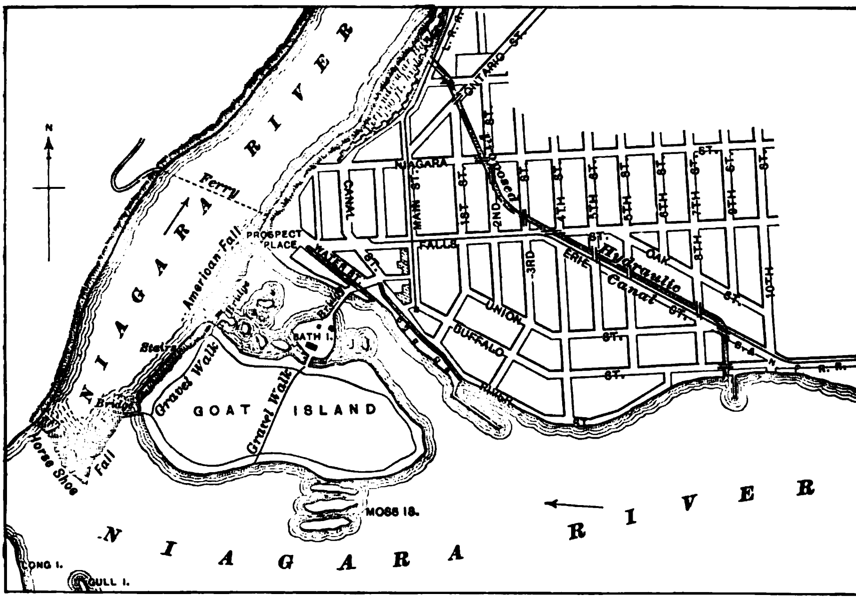
And why should it not be so? Nearly 6000 cubic miles of water, pouring down from the upper lakes with 90,000 square miles of reservoir area, reach this gorge of the Niagara river at a point where its extreme width of one mile is by islands reduced to two channels of only 3800 feet. Here, in less than half a mile of rapids, the Niagara river falls 55 feet, and then, with a depth of about 20 feet at the crest of the Horse Shoe Falls, plunges 165 feet more into the lower river. The ordinary flow has been found to be about 275,000 cubic feet per second, and in its daily force, equal to the latent power of all the coal mined in the world each day—something more than 200,000 tons.

This natural comparison at once suggests, as through the century it has invited, an estimate of this power in the terms of mechanics, and it has been computed by Professor Unwin that these falls represent theoretically seven million horse-power (others think more), and for practical use, without appreciable diminution of the natural beauty, several hundreds of thousands of horse-power. The idea of subjecting to industrial uses some part of the enormous power of Niagara Falls has, since the location of the pioneer saw-mill in 1725, occupied the minds and stirred the inventive faculty of engineers, mechanics and manufacturers. Early in the century, the pioneers in the locality, to which

A VIEW OF THE OLD MILLING DISTRICT.



FROM GOAT ISLAND, LOOKING TOWARDS LUNA ISLAND.



PETER EMSLIE'S MAP, SHOWING THE EARLY CANAL AND RESERVOIR PROPOSED IN 1846.

they then gave the name of Manchester, contemplated the probability, but were unable to demonstrate the practicability, of reducing this mighty force to obedient and useful service. They dwelt upon, and to some extent exploited, the idea; but before the development or adoption of any method promising satisfactory returns, steam and steam engines had properly attained such a place in the favourable estimation of manufacturers that water-powers in general, and especially those inconveniently situated and variable in quantity and quality, fell into comparative disesteem.

The economical production and distribution of coal for use in connection with the engines developed by the genius of Corliss and his fellows, naturally led manufacturers to prefer to produce their own power at their own homes or in proximity to favourable markets, rather than to set out in search of remote and uncertain water-powers. But some water-powers were operated and continuously employed, notwithstanding, and even during, the steady development of the advantages of steam power. No one needs much persuasion to admit that, except for the decided merits of water-power even in competition with steam, the names of Manchester, Lowell, Lawrence, Holyoke, Paterson, Cohoes and Minneapolis, in the United States, would possess nothing like their present significance.

In view of the obvious advantages offered by water-powers such as these, Augustus Porter, one of the principal proprietors at Niagara, in 1842 proposed a considerable extension of the system of canals or races then employed, and in January, 1847, in connection with Peter Emslie, a civil engineer, he published a formal plan, which became the subject of negotiations with Walter Bryant and Caleb S. Woodhull, formerly Mayor of New York. An agreement was finally reached with these gentlemen by which they were to construct a canal, for which they were to receive a right of way, 100 feet in width, together with a certain amount of land at its terminus. After various interruptions, in 1861, their successor, Horace H. Day, completed a canal, about 35 feet in width, 8 feet in depth

THE NIAGARA FALLS RAILWAY SUSPENSION BRIDGE.

and 4400 feet in length, by which the water of the upper Niagara river was brought to a basin or reservoir at the high bluff of the lower river, 214 feet above the water below. Upon the margin of this basin have been constructed various mills, to whose wheels the water was conducted from the canal and discharged by short tunnels through the bluff into the river below, so that in 1885, about 10,000 horse-power, substantially the available capacity of the canal, was in use.

In that year there happened to be at Niagara an able and experienced engineer, engaged in the State's service in laying out a proposed reservation, just as nearly 50 years before he had been there engaged in assisting the State Geological Survey of Prof. James Hall, who, in his report on the Niagara river district for 1843, specially mentions the services of Thomas Evershed. During this very long interval, Mr. Evershed had been engaged as a public engineer, usually upon the Erie canal in that vicinity, and it was natural that he should be called upon to devise a system for the development of hydraulic power from the river with which his whole professional career had been associated, his last great work being in connection with the effort to protect Niagara, in its principal character as the most magnificent and impressive terrestrial natural object, from vandalism and utilitarian desecration. This protection of the natural beauty of Niagara was the underlying idea in his conception and development of his plan, which contemplated the taking of water and the development of power in a district more than a mile above, and out of sight of the Falls, with an outlet tunnel discharging inconspicuously at the river's edge below the Falls, involving the diversion of less than four per cent of the total flow of the river, and a reduction of the depth of the water at the crest of the Falls by less than two inches.

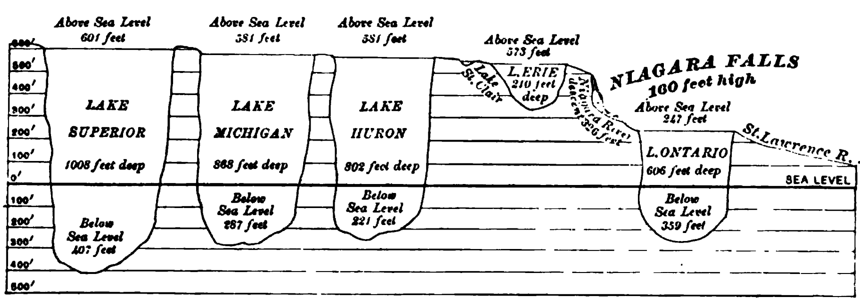
After conference with Mr. Evershed, Capt. Charles B. Gaskill, the oldest user of power on the hydraulic canal, with seven other gentlemen of Niagara Falls, obtained from the legislature of the State of New York, a special charter, passed March 31, 1886, which has since been amended and enlarged by several successive acts. Upon July

1, 1886, Mr. Evershed issued his first formal plan and estimate, which was considered worthy of discussion in Appleton's Cyclopædia for 1887, where it is described in general terms. But, of course, the publication of this plan invited and encountered the demonstration of its absolute impracticability, as well as the improbability of the use of the power if developed. In Bradstreets, October 30, 1886, appeared a letter from Mr. Edward Atkinson (completely answered by Mr. Clemens Herschel on November 6, 1886), undertaking to show that cheap power alone would not bring people to Niagara Falls; and, somewhat later, on August 8, 1889, there appeared in The Nation, a carefully written article tending to show that Mr. Evershed's tunnel would not be practicable for the production of power, nor commercially profitable. But strange to say, these objections have been fully answered through the demonstration of actual experience.

For three years the originators of the Niagara water-power project were engaged in convincing capitalists that it would be commercially profitable to undertake and complete the development of Mr. Evershed's plan, and the first step necessary to be taken was to demonstrate the advantages of the locality. It was shown that the capacity of the original tunnel, about 120,000 horse-power, would exceed the combined theoretical horse-power of Lawrence, Lowell, Holyoke, Turners Falls, Manchester, Windsor Locks, Bellows Falls and Cohoes, and would very largely exceed the actually developed power of all these places, and Augusta, Paterson and Minneapolis in addition. Considering the further right to construct an additional tunnel of 100,000 horse-power on the American side, and to develop at least 250,000 horse-power on the Canadian side, it was readily recognized how vastly this local development promised, in extent, to surpass the combined water-powers of almost any American State or section.

In the special volume upon water-power, constituting part of the United States census of 1880, it is stated that there were then in operation 55,404 water wheels, with an average of 22.12 horse-power each, making in the aggregate 1,225,379 horse-power. It thus appeared that the 450,000 horse-power available to the Niagara Falls Power Company represented more than a third of the power of all the wheels in the United States in 1880.

The question of the practical importance of the Niagara power being settled, Mr. Atkinson's next question arose as to the advantages of Niagara as a locality, and to this, answer was readily made by pointing out that there in the very heart of densest population, touched by nearly all the East and West trunk-lines, within a night's journey of Boston, New York, Philadelphia, Washington, Pittsburgh, Cincinnati, Cleveland, Chicago, Toronto and Montreal, was a natural port of the great lakes, sustained by a salubrious and fruitful



DEPTHS AND LEVELS OF THE GREAT LAKES.

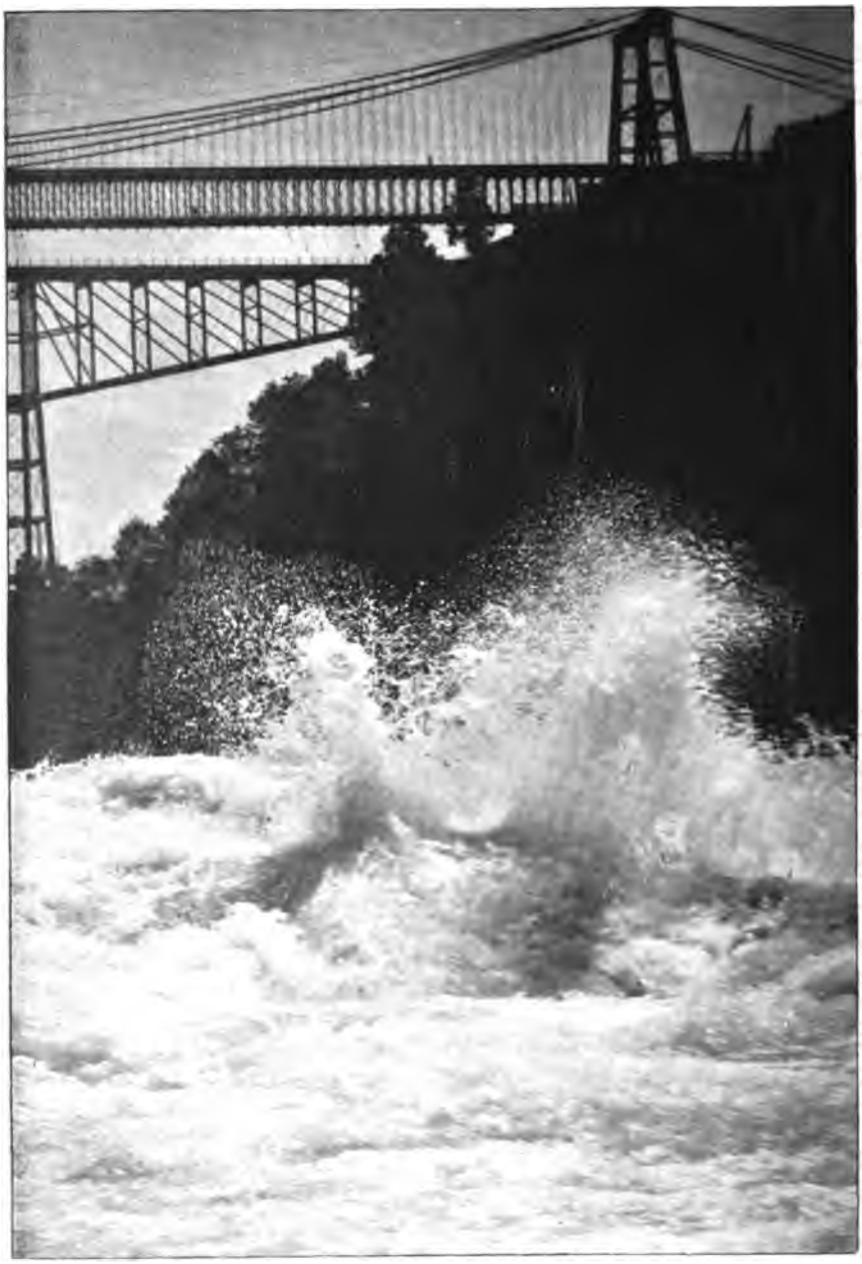
country, and protected by the orderly and established institutions and traditions of the most opulent and populous of the States of the Union. The existence of manufacturing establishments sufficient to exhaust all of the power then supplied by the hydraulic canal, and the subsequent applications for the new power, were and are the complete answer to the question whether, as a locality, Niagara would be attractive to users of power.

But the question still remained whether water-power could be used successfully in competition with steam, and there are few places in respect of which this question can be asked with more deadly effect; for, in the city of Buffalo, and indeed through the entire length of the district lying north of Pittsburgh, good steaming coal can be obtained at less than $1.50 a ton. With coal at this price, it would, at first, seem impracticable to establish any power plant capable of operating in competition with steam. But a careful examination has satisfied me, at least, that with coal furnished free at the furnace yard, it would still be economical for the manufacturer to employ water-power such as that at Niagara. When in England in 1890, I was told by an eminent gentleman that it was useless to discuss the profitable employment of water-power, for, as he said, "you can produce steam-power from coal at a cost of a farthing an hour," to which I answered:—"Very well, let us work out the problem! Coal, at a farthing an hour, would, in America, represent five cents for a day of ten hours, or 12 cents for a day of 24 hours, which is, for 300 days in the year, $15 for the short day and $36 for the long day for fuel only. At Niagara we will gladly furnish continuous 24-hour water-power for $15 a year, in any considerable quantity."

After careful consideration, the officers of the Niagara Falls Power Company reached the conclusions that 24-hour steam horse-power is not produced anywhere in the world for less than $24 a year; that in the production of the steam-power the cost of the fuel does not represent more than one-half of the total cost; that very few, if any, manufacturers have ever kept any separate account of the cost of their power, or have any actual knowledge of its cost; and that, aside from the cost of the power, many conveniences will come from the employment of power as it may be furnished from the Niagara river.

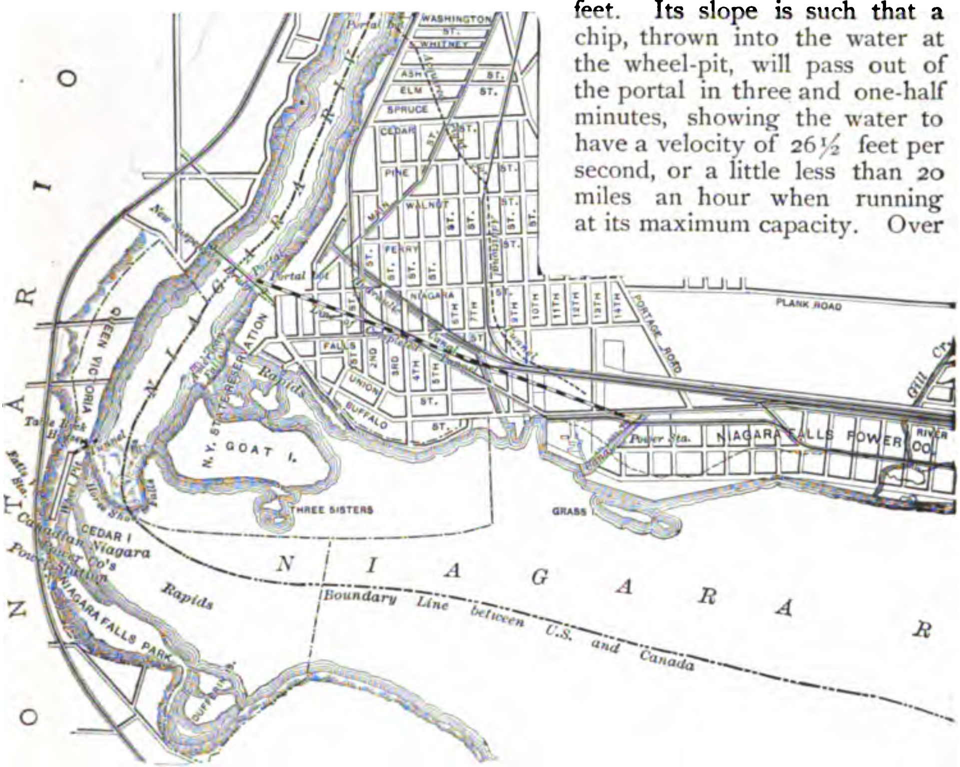
In view of all these considerations, in the year 1889 the present interests in the Niagara Falls power development were combined in a new corporation called the Cataract Construction Company, whose acceptance of the construction contract rested upon two propositions: First, that with proper organization and development the Niagara project would be valuable solely as a hydraulic installation; and, secondly, that it gave promise of becoming, within the very near future, vastly more valuable as a source of power for transmission. This company was the outgrowth of the very keen and appreciative interest in these propositions shown by the following gentlemen in the order named: William B. Rankine, Francis Lynde Stetson, J. Pierpont Morgan, Hamilton McK. Twombly, Edward A. Wickes, Morris K. Jesup, Darius Ogden Mills, Charles F. Clark, Edward D. Adams, Charles Lanier, A.J. Forbes-Leith, Walter Howe, John Crosby Brown, Frederick W. Whitridge, William K. Vanderbilt, George S. Bowdoin, Joseph Larocque, Charles A. Sweet of Buffalo and John Jacob Astor, most of whom have served as officers and directors of the construction company, giving freely of their time and experience to the conduct of the enterprise. Among all these names it may seem invidious to select any for special comment, but, after the early and continuing interest of Mr. Morgan and Mr. Mills, and the later accession of Mr. Astor, it was, as it continues to be, a matter of congratulation to the Cataract Construction Company that the origination, the development and the guidance of its affairs have, from the first, received the intelligent and continuous attention of its president, Mr. Edward D. Adams.

NEAR PROSPECT POINT AT NIGHT.



THE WHIRLPOOL RAPIDS BELOW THE FALLS.

In the order of development, of course, the first step was the adoption of a general plan. Dr. Coleman Sellers of Philadelphia having been retained as general consulting engineer, Mr. Clemens Herschel, formerly of Holyoke, was engaged as hydraulic engineer, and, in accordance with the views of these gentlemen, some slight modifications of Mr. Evershed's proposition were adopted. Generally speaking, the final plan comprises a surface canal, 250 feet in width at its mouth, on the margin of the Niagara river, a mile and a quarter above the Falls, extending inwardly 1700 feet, with an average depth of about 12 feet, serving water sufficient for the development of about 100,000 horse-power. The solid masonry walls of this canal are pierced at intervals with ten inlets, guarded by gates which permit the delivery of water to the wheel-pit in the power house at the side of the canal. This wheel-pit is 178 feet in depth, and is connected by a lateral tunnel with the main tunnel, serving the purpose of a tail-race, 7000 feet in length, with an average hydraulic slope of six feet in 1000, the tunnel having a maximum height of 21 feet and width of 18 feet 10 inches, its net section being 386 square feet. Its slope is such that a chip, thrown into the water at the wheel-pit, will pass out of the portal in three and one-half minutes, showing the water to have a velocity of 26½ feet per second, or a little less than 20 miles an hour when running at its maximum capacity. Over 1000 men were engaged continuously for more than three years in the construction of this tunnel, which called for the removal of more than 300,000 tons of rock, and the use of more than 16,000,000 bricks for lining. The construction of the canal, and especially of the wheel-pit, 178 feet in length, with its surmounting power-house, were works of corresponding difficulty and importance.



MAP OF NIAGARA FALLS AND VICINITY, SHOWING THE LOCATION OF THE GREAT TUNNEL.

After conference with various wheel-makers in the United States, it was

Prof. E. Mascart. Prof. W. C. Unwin. Lord Kelvin. Dr Coleman Sellers. Col. Th. Turrettini.

THE INTERNATIONAL NIAGARA FALLS COMMISSION.

found that while American water-wheels of standard grades could be obtained of considerable excellence, yet, except in the case of the Pelton water-wheel, it was not easy to find wheels suitable for special requirements such as those of the Niagara Falls Power Company. The conclusion, therefore, to consider the employment of wheels of special design, which, in the nature of things, involved conference with foreign makers, to whom alone special design had become a matter of frequent occurrence, was reached upon the advice of Mr. Clemens Herschel, who was familiar with the use of the wheels at Holyoke which he had made a subject of careful study. The fact that Mr. Herschel himself advised recourse to foreign designers is a sufficient answer to some New England criticism that we did not adopt wheels such as have been used at Holyoke.

But, as soon as careful consideration was given to the subject of turbines, it also became quite apparent that it was desirable, contemporaneously and from the beginning, to take up and examine the question of power transmission, and it became equally apparent that by reason of the rapid advance in the art and science of the development and transmission of power, even the latest books upon this subject had become inadequate to our demand for information. In consequence of these conditions, Mr. Adams, while in Europe in the winter of 1890, happily conceived the idea of obtaining and perpetuating information as to the results and achievements of the engineers and manufacturers of the world not yet in the books, and, in conformity with this purpose, established in London, in June, 1890, an International Niagara Commission, with power to award $22,000 in prizes.

The commission consisted of Sir William Thomson (now Lord Kelvin) as chairman, with Dr. Coleman Sellers of Philadelphia, Lieut.-Col. Theodore Turrettini of Geneva, Switzerland, originator and engineer of the great water-power installation on the Rhone, and Prof. E. Mascart of the College of France, as members, and Prof. William Cawthorne Unwin, Dean of the Central Institute of the Guilds of the City of London, as secretary. Inquiries and examination concerning the best known existing methods of development and transmission in England, France, Switzerland and Italy, were made personally by the officers and engineers of the company, and competitive plans were received from twenty carefully selected engineers, designers, manufacturers and users of power in England and the Continent of Europe and also in America. All of these plans were submitted to the commission at London on or before January 1, 1891, and awards of prizes were made in respect of a number of the plans considered worthy by the commission.

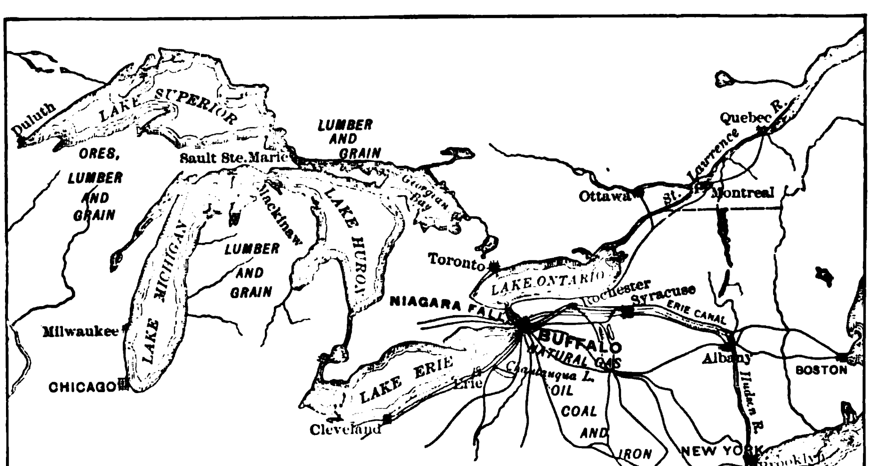
The first important result of this commission was the selection of Messrs. Faesch & Piccard of Geneva, as designers of the turbines, of which a careful description by Mr. Clemens Herschel is given elsewhere in this magazine. It is enough here to say that these wheels, calculated to yield 5000 horse-power each, are intended for a position in the wheel-pit, 140 feet below the surface, to which water is conducted by a tube or pen-stock leading from the service canal and discharging between the twin wheels, from which the water falls away into the side tunnel conducting it to the main tunnel and thus to the lower river. The power, of course, is developed through the drop in the wheel-pit, the tunnel serving the purpose only of a tail-race. Three of these wheels have actually been built after designs of Faesch & Piccard, by the I. P. Morris Company, of Philadelphia, and are now in place. They are about five feet in diameter. The pen-stock, 7½ feet in diameter, is made of steel, and the constant pressure of its column of water, discharging between the twin turbine wheels, serves to support the entire weight of all the revolving parts, namely, the weight of the wheels, the vertical shaft and the revolving parts of the generator driven by the wheel, to which reference will be hereafter made.

The mechanical problem to be solved in this case, viz.: how to get 5000

horse-power from the point of development at the wheels to the surface, 140 feet above, was considered to be much less difficult than that presented in the case of an Atlantic steamer, where the motive power of the 5000 horse-power engine is delivered by a horizontal shaft to the screw at the stern of the vessel, more than 140 feet away, the water-wheels at Niagara being our engine, the generator at the surface, our screw, and the connecting shaft (adopted in preference to belting or ropes), 140 feet in length, being vertical instead of horizontal. This shaft is of steel, ¾ inch thick, carefully rolled into tubes, 38 inches in diameter, without any riveted vertical seams; but at several intervals, where journals are needed to steady this vertical shaft on fixed collar bearings, it is solid and at those points measures 11 inches in diameter. While these turbines were made after foreign designs, the contract for building them was given to and was performed by the I. P. Morris Company, of Philadelphia, and, upon the observation of competent and disinterested experts, the Niagara Falls Power Company feels no hesitation in inviting general observation and criticism of this unusually difficult construction.

The question of the turbines having been thus disposed of, it became necessary to determine upon the mode of transmitting the power to be developed from them, and to this subject the careful attention of the officers and engineers of the company was addressed for more than three years, both in America and Europe. In 1890, four different methods of power transmission were seriously considered, viz., that by manilla or wire rope, that by hydraulic pipes, that by compressed air, and that by electricity. How rapid has been the progress of thought upon this subject within four years, may be realized when I say that in 1890, I was advised that power could be transmitted from Niagara to Buffalo, not by electricity, but only by compressed air, and that my adviser was Mr. George Westinghouse. But methods are clearer now than in 1890, and this largely is the result of the competition initiated by the International Niagara Commission.

Rapidly summarizing the results and incidents of a tour of inspection made by Mr. John Bogart, one of the engineers of the company, and myself, in 1890, I may observe that we saw five instances of transmission of power by manilla or wire ropes, viz., at Schaffhausen, Winterthur, Zurich and Fribourg, in Switzerland, and at Bellegrade, in France,



BUFFALO AND THE TERRITORY WHICH PAYS HER TRIBUTE.

NIAGARA FALLS IN WINTER.

all of these installations representing the effect of the original installation under Mr. Moser at Schaffhausen in 1867. Mr. Moser, a gentleman of great intelligence, was among the first to observe that the use of water-power had declined, and that the preference for steam-power had developed, because of the common inconvenience of the bringing of the factory to the source of the water-power, which inconvenience he thought to obviate by taking the power to the convenient site of the factory. This he did by the use of the wire ropes, sometimes to the distance of nearly a mile. But while this device served a useful purpose, it developed its own difficulties, especially in localities affected by cold or frost, under which conditions the wire rope frequently slipped on the wheels, an occurrence disastrous to spinning-mills, and which at Schaffhausen, is now leading to the substitution of electricity for the original wire transmission.

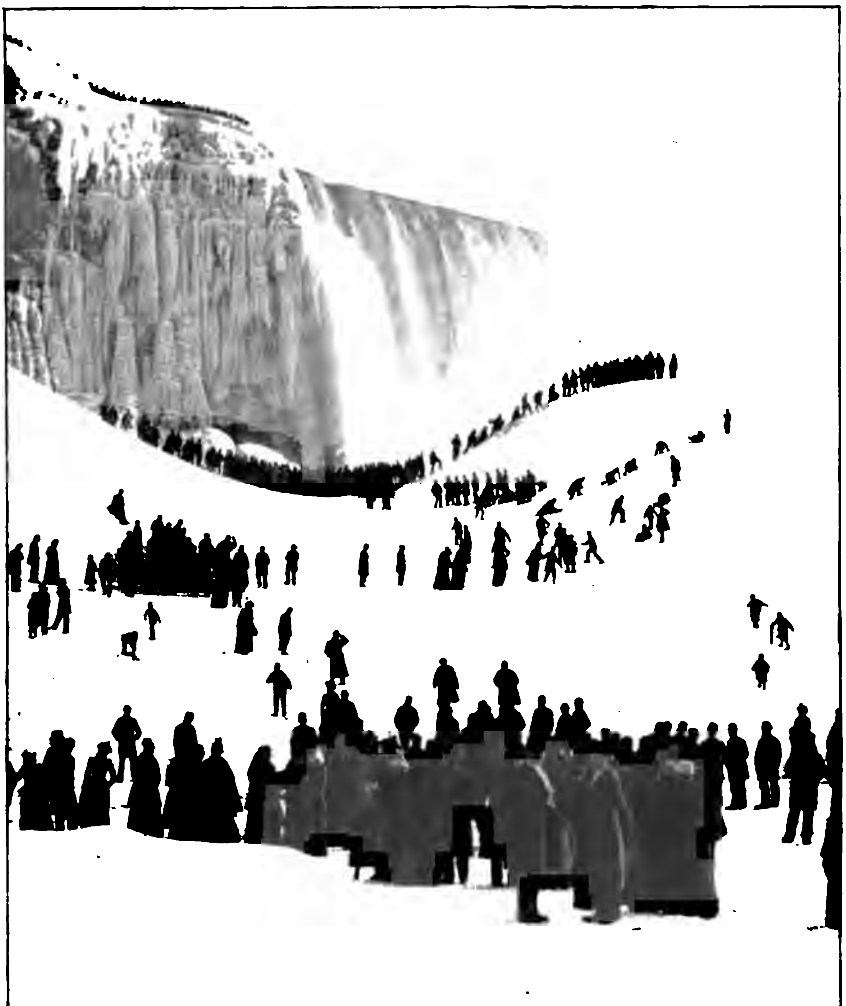
The second system of transmission visited by us was that upon a very large scale at Geneva, in Switzerland, instituted under the direction of Col. Turrettini, viz., hydraulic transmission of hydraulic power from the turbines, through pipes to different parts of the city, even for the purpose of operating dynamos for electric lighting. While this method of hydraulic transmission at Geneva did excellent work, it was already recognized in 1890 that it was not equal to electrical transmission of power, and in the duplication of the work now being made under the direction of Col. Turrettini, electricity is substituted as the means of transmission.

The third system of transmission, the pneumatic, had been developed to a very large extent in Paris, upon the system of Mr. Popp, under the observation of that most accomplished engineer, Prof. Riedler. Immense steam-power plants were established at Belleville, nearly seven miles

from the center of Paris, and at other points, and by the use of compressors over 7000 horse-power was distributed throughout Paris, operating more than 30,000 pneumatic clocks in the hotels and residences, supplying refrigeration for the stores for meats in the Bourse de Commerce, and also an installation for electric lighting near the Madeleine. We also observed the Sturgeon & Lupton system of pneumatic transmission in Birmingham, and later the important example of such transmission from the Menominee river, seven miles away, to the Chapin iron mine, at Iron Mountain, in Michigan. This was the system which, in 1890, Mr. Westinghouse thought we were likely to adopt. But, in view of the great loss of power, the Popp system yielding only 38 per cent. in efficiency, and the Birmingham system yielding only 52 per cent., upon comparatively short distances, it did not seem wise to the Niagara Falls Power Company to adopt this system, useful and valuable as it is in many particulars; but it is gratifying to be able to state that in the International Niagara competition a prize for a project for distributing power pneumatically, was awarded to the Norwalk Iron Works Company, of Connecticut.

A very interesting debate as to the comparative merits of electricity and compressed air was conducted in September, 1890, in my presence, between Prof. Riedler in behalf of compressed air, and Mr. Ferranti in behalf of electricity. Mr. Ferranti said that the electrical system was especially adapted to long transmission of great volumes, inasmuch as the loss increased only inversely as the square of the increase of volume; that is, if a loss of 50 per cent. were to be assumed for transmission of 5000 volts, that loss would increase only one-half upon doubling the volume—in other words, a transmission of 5000 volts with a loss of 50 per cent. might be increased to 10,000 volts with a loss of only 25 cent. of the increase, or 37½ per cent. of the aggregate amount, or, stated concretely, though 5000 volts might yield only 2500 volts, 10,000 would yield 6250 volts of the power developed. Prof. Riedler was greatly puzzled by Mr. Ferranti's positive statement, and said that, if well founded, the loss in the case of electricity differed from that of every other known force, to which Mr. Ferranti replied that this undoubtedly was so, and that the differences were altogether to the advantage of its employment upon a great scale for such a service as this. Prof. Riedler concluded by saying to Mr. Ferranti that if his statements were well founded, there could be no question but that electricity must prevail over compressed air. This was in 1890, and all subsequent experience has tended to confirm the statements of Mr. Ferranti, Mr. Nikola Tesla having quite recently stated to me that if the company would put 100,000 horse-power upon a wire, he would deliver it at commercial profit in the city of New York.

The fourth method of power transmission was that by electricity, which we found in actual operation in three places, all in France—Oyannax, Doméne and Paris, besides the short transmission within the buildings of the Oerlikon Company, near Zurich, in Switzerland. Other examples, contemporaneously or subsequently developed, might be referred to, but these are they upon which, in 1890, the Niagara Company founded its preference for electrical transmission. At Oyannax, on the Jura Mountains, in the Department of Ain, there was a variety of small interests, the principal one being the manufacture of silk, the smaller ones being the manufacture of tortoise-shell combs and other lighter articles, in which not more than two or three horse-powers were employed for the running of small saws and polishers. The power for these various simple industries was derived from turbines in the Ain river at Charminet, distant in a direct line about five miles from the use of the power. At Doméne, opposite the Grande Chartreuse, in the Dauphiny Alps, the power for a paper mill was drawn from a glacier in the mountain, four miles away, almost straight up in the sky, and in winter actually inaccessible, so that for three months the only communication between



ICE BRIDGE UNDER THE FALLS.

THE HORSESHOE FALLS FROM GOAT ISLAND.

the mill and its source of power was by telephone. Here, sleety storms prevail, and snow and frost to an extent equal to that conceivable at Niagara, and yet the results were so satisfactory that Mr. Chevrant, the owner of the mill, said that his power did not cost him over 50 francs a year.

But passing from these examples of 1890, through the larger experience by which power was transmitted 16 miles from Tivoli to Rome, and for a long distance at Portland, Oregon, and also at Telluride, in Colorado, in all which places power, generated at a water-power station, is transmitted with bare copper wires on poles for ten miles and more with commercial success, the Niagara Company, in December, 1891, under the advice of Prof. Rowland, of Johns Hopkins University, Prof. George Forbes, of London, and Prof. Sellers, of Philadelphia, invited competitive plans and estimates for the development ot its electrical power and of its transmission both locally and at Buffalo. As the result of this advice and this competition, the company adopted a two-phase alternating generator of 5000 horse-power, developing about 2000 volts with a frequency of 25, as the best practicable unit and method for the development of electricity for power purposes. It is distinctly recognized that a higher frequency in the present state of the art is desirable for arc lighting, and is necessary for incandescent lighting; but having regard to the special purpose, and conditions of this company, it was decided to adopt that method and system which is, on the whole, best fitted for a power company as distinguished from a light company. It is only proper to say that in the adoption of the alternating system, as opposed to the continuous system, in the adoption of the two-phase, as distinguished from the three-phase, and in the adoption of the frequency of 25, the company was diversely advised and criticised, and the result finally reached was that which, upon the whole, under existing, present conditions, seemed best.

ANOTHER VIEW NEAR PROSPECT POINT.

The form of dynamo employed is that devised by the company's electrical engineer, Prof. George Forbes, of London, resembling a mushroom or umbrella, in which the stalk or handle is the shaft of the turbine, and the cap is the revolving part of the generator, serving the purpose also of a fly-wheel for the turbine, this special advantage having resulted from Prof. Forbes' happy idea of a dynamo in which the field magnets should revolve instead of the armature. A contract for three such dynamos, of 5000 horse-power each, was made with, and was performed by,

the Westinghouse Company at Pittsburgh. The first users of the power developed from these dynamos were the Pittsburgh Reduction Works, manufacturers of aluminum, having an establishment also at Pittsburgh. Their works at Niagara are upon the lands of the company, 2500 feet distant from the power-house, which is reached by an underground conduit for electrical transmission. After a competition for a design and construction of works suitable for the transmission of electrical power to this establishment, and for converting the alternating into a continuous current, a contract was made with, and carried out by, the General Electric Company, of Schenectady, N.Y. At the same time, both the Westinghouse Company and the General Electric Company, in competition, have submited plans for the transmission of electric power to Buffalo, and, upon the adoption of the successful plan, the Niagara Falls Power Company is prepared to proceed with the construction and operation of a plant for transmission of electricity to that important city on Lake Erie.

How much farther such power may be transmitted at a commercial profit remains to be seen. Messrs. Houston & Kennelly, well known electrical engineers, independently reached the conclusion that even so far away as Albany (a distance of 330 miles) electrical power, with a steady load of 24 hours per day, can be delivered at $22.14 per kilowatt, which is cheaper than it can be produced by triple-expansion steam engines, though the cost would be proportionately greater for 10-hour power. Though these figures are gratifying, they are not those upon which the Niagara Falls Power Company is resting for the success of its undertaking. Whether or not electrical power can be furnished 330 miles away at less than $24 a day for 24-hour horse-power, it can, within much nearer distances, be furnished at such prices as to leave very little surplus power for distribution at such remote points ; and, on the other hand, if it be practicable to transmit power at a commercial profit in these moderate quantities to Albany, the courage of the practical man will not halt there, but, inclined to follow the daring promise of Nikola Tesla, would be disposed to place 100,000 horse-power on a wire and send it 450 miles in one direction to New York, the Metropolis of the East, and 500 miles in the other direction to Chicago, the Metropolis of the West, and serve the purposes and supply the wants of these greatest urban communities.

Conscious of the difficulties of transferring, at once, large industries to a new site, even as attractive as it has made Niagara, with its new industrial village of Echota, designed by Stanford White, and the new Terminal Railroad owned by kindred corporations, the Power Company, notwithstanding encouragement from such home tenants as the great Paper Company and the Aluminium and the Carborundum works, has definitely determined to furnish its power to distant consumers, even at the risk of work which, in some measure, must be experimental, though not in so large a degree as many may suppose. Tivoli, Turin, Telluride, Genoa, Williamette, San Bernardino, all tell that commercial success lies back of the brilliant experiment, in 1891, of Lauffen and Frankfort, 109 miles apart.

Buffalo, being reached, is only on the way to points beyond. How far beyond, it is not necessary now to determine ; but having once set in motion these mighty wheels, we may at least imagine and admire a bow of brilliant promise,—an arc of electrical energy stretching from the Metropolis of the Atlantic to the Metropolis of Lake Michigan, whose waters, swelling the mighty flood that stirs Niagara, may then be called upon to drive

"The roaring loom of time itself."

W. C. Unwin

Prof. Wm. Cawthorne Unwin is one ot the best known engineers, authors and teachers of engineering science in England, as well as in America. He was a member of International Niagara Falls Commission.

MECHANICAL ENERGY AND INDUSTRIAL PROGRESS.

By W. Cawthorne Unwin, F. R. S.

IT is an honour to have been invited to contribute a short article to a number of CASSIER'S MAGAZINE, devoted to a description of the work at Niagara, and it is pleasant to be so associated with those who have had the task of planning the arrangements, superintending the works and designing the machinery of that grand installation. Writing, however, on the European side of the Atlantic, it will be wisest,—not to say most modest,—to avoid details and to deal, in preference, with some general consideration bearing on the question of utilizing and distributing power.

In all producing industries, there are operations requiring greater, and operations requiring less, intelligence; operations requiring great manual skill, and others requiring little manual skill. The sub-division of labour which has arisen in modern industries has for its object to economize the intelligence and skill and other special faculties of the workers. A factory should be so arranged that manufacture is carried on by the most advantageous number of processes, each worker doing what he is best fitted to do, and the number of workers in each class being proportioned to the requirement of the process allotted to it. The sub-division of manufacture in this way greatly facilitates the introduction of machinery, and with the use of machinery comes the need for motive power, more constant and tireless than muscular effort. Comparing the last hundred years with any previous period, their most obvious characteristic is the enormous extension of the use of mechanical energy derived from natural sources.

At first, factories were placed near waterfalls from which alone, at that time, mechanical energy could be easily obtained in sufficient quantity. Then, about the year 1790, steam power began to replace water power. For a time, the factories were aggregated near coal fields. To some extent this is still the case, though facilities of transport, due again to the use of natural supplies of energy, permit manufactures to spread more widely. In any case, the location and the growth of manufactures have been largely determined by facilities for obtaining cheaply large quantities of power.

In 1832, Charles Babbage, the inventor of the well-known calculating engine, published an interesting work on "The Economy of Machinery and Manufactures." It deals with the guiding principles underlying modern methods of manufacture, then already so far developed as to be recognized as constituting a new system. It is curious that Babbage says little about the production of power or its cost, though, clearly, the use of cheap steam power was the principal factor in the industrial change which he discusses. Towards the end of the book, however, he does mention that the application of the steam engine had added millions to the population of Great Britain.* Then

* Mr. Thomas Hawksley often said that the population of Great Britain had trebled in his lifetime.

THE HORSE SHOE FALLS AT NIAGARA.

he points out that the source of steam power,—the fuel,—is limited in quantity, and that a time may come when the coal mines will be exhausted. He mentions the tides as an inexhaustible source of energy, if means could be found for utilizing tidal action.

Finally, he indulges in a curious speculation. He points out that hot springs, which have been observed to flow for centuries, unchanged in temperature, bring to the surface a practically unlimited supply of heat. "In Iceland," he says, "the sources of heat are plentiful and their proximity to large masses of ice almost points out

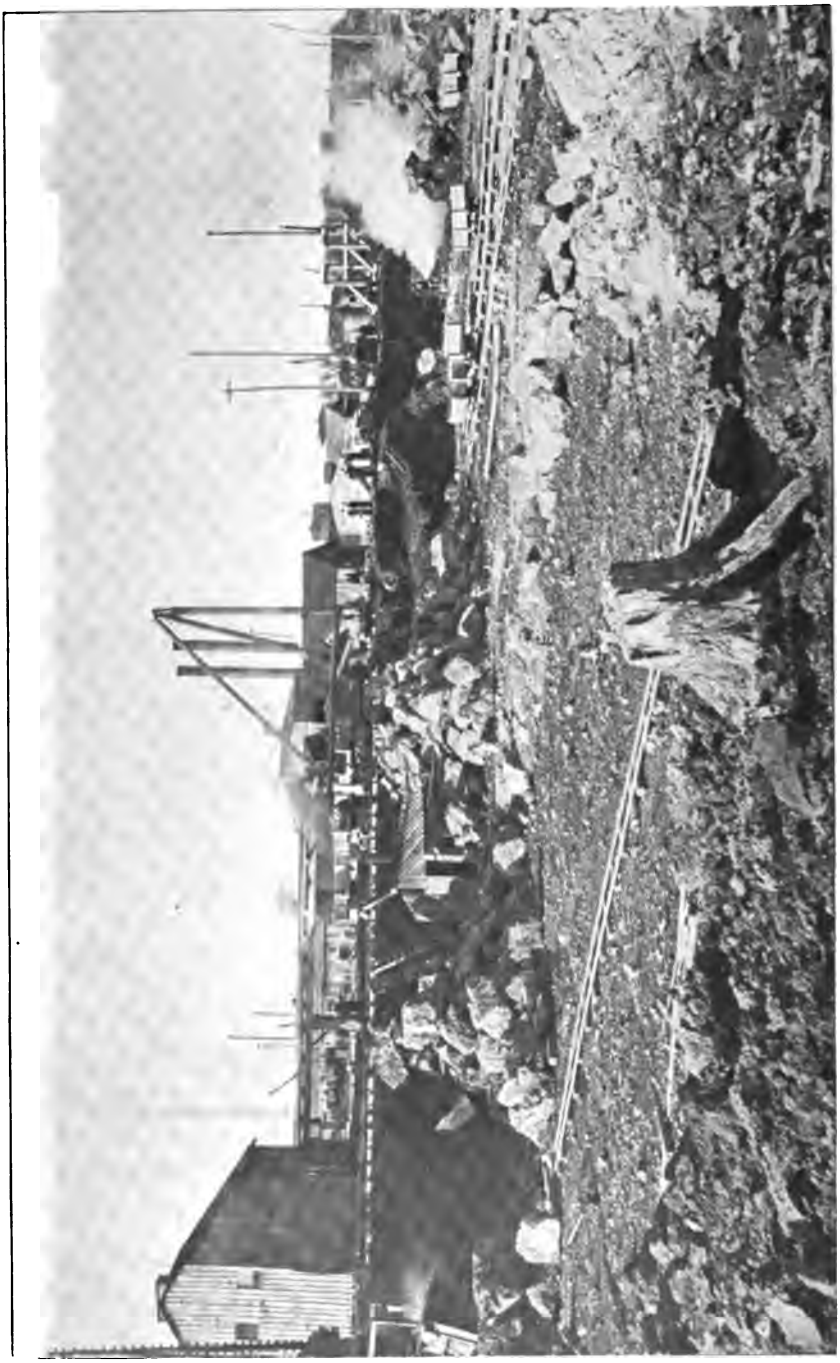
the future destiny of that island. The ice of its glaciers may enable its inhabitants to liquefy the gases with the least expenditure of mechanical force, and the heat of its volcanoes may supply the power necessary for their condensation. Thus, in a future age, power may become the staple commodity of the Icelanders."

Manufacturers have not yet been driven to obtain power by purchasing liquefied oxygen in Iceland. The coal fields are not yet exhausted. But the pressure on trade of the cost of the energy required is undoubtedly felt. This may be inferred from the ceaseless efforts to reduce the consumption of steam in engines, and to improve the efficiency of boilers. There are obvious causes for this. As trade competition becomes more severe, every item of expenditure in carrying on work is scrutinized, and out of many small economies a material advantage is reaped. Even if in some industries the annual cost of power is a small fraction of the total expenditure, any saving on it is a clear addition to profits.

In many industries there is an increasing consumption of power, processes being multiplied to secure greater perfection of product, and then the cost of power is an increasing tax. Lastly, there are new electrical and chemico-electric industries in which the amount of power used is very large, and its cost is not a small fraction of the expenditure. In electrical industries, mechanical energy is virtually the raw material of the manufacture, and its cost is not a subordinate, but a principal, factor in the cost of production.

In an article in *Engineering*, several years ago, Dr. Coleman Sellers quoted some estimates of the amount of power required in different industries. These

THE FALLS NEAR PROSPECT POINT.



BEGINNING THE POWER CANAL AT NIAGARA.

are given conveniently in horse-power per artizan or worker employed. Taking the cost of one horse-power year at about £12 or $60, which is a moderate, average estimate, the annual expenditure per worker can be calculated in supplying the mechanical energy necessary to make his labour effective.

Industry.	Horse-power for each hand employed.	Cost per annum per hand employed. £	s.	$
Flour and grist mills	13.20	158	8	(792)
Lumber sawing.....	5.56	66	12	(333)
Cotton..............	1.49	17	16	(89)
Paper..............	5.07	60	16	(304)
Woollen goods.....	1.23	14	16	(74)
Iron and steel......	2.82	33	16	(169)
Agric'ral implem'ts.	1.13	13	12	(68)
Worsted goods.....	0.87	10	8	(52)

The figures in the last column are the annual charges, additional to his wages, for each worker for the mechanical energy he uses. Obviously, these charges are not amongst the negligably small items of a manufacturer's expenses.

In the case of electric lighting stations, the proportionate cost of power is enormously greater. From figures known to be reliable, it appears that in stations in England the cost of fuel alone per electrical unit sold, apart from interest on cost of boilers and engines and wages and maintenance, is seldom less than one penny, and is, in some cases, double this. But the ordinary selling price of electricity is 6 pence per unit, so that the fuel cost alone absorbs one-sixth of the gross income of the works, and in some cases one-third.

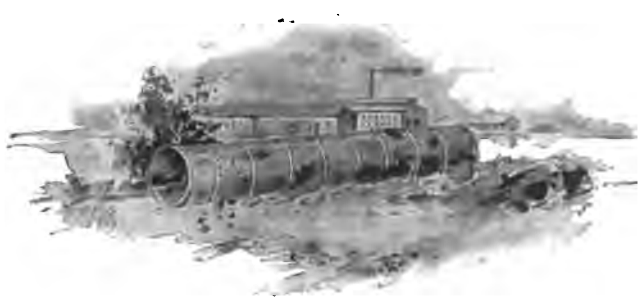
IN THE NIAGARA WHEEL-PIT DURING CONSTRUCTION.

Up to the present time by far the largest part of the mechanical energy used in the world has been derived from the combustion of fuel. But in the best steam engines the limit of possible economy has been nearly reached. A good deal may be effected, no doubt, by replacing bad engines and boilers by good engines and boilers, but there is little reason to hope that any steam machinery of the future will work with materially greater economy than the best at present in use. Nor is there much hope of considerable economy from the improvement of other heat

engines. Short of going to Iceland, there is only one widely distributed, easily utilizable source of mechanical energy, and that is water power.

Under favourable conditions, and utilized on a large scale, the cost of water power near the waterfall may be one-tenth or one-twentieth of the cost of steam power. The difference is so great that even when considerable cost is incurred in transmitting the power from the waterfall to localities where power is required, there may be a margin of economy in using water power. No doubt, in many cases, especially where very great, permanent structures had to be erected to render falls of considerable height available, water power has proved as expensive as steam power.

Modern facilities of transmission and distribution have greatly altered the conditions of the problem, and engineers in several countries have come to realize the value of the waste energy of the streams. No one can now travel in Switzerland or southern Norway without perceiving that a new impetus has been given to industry by the development of large water power plants. In Norway a new industry,—the paper pulp trade,—has, in a few years, become extremely important, and the manufacture is carried on entirely by cheap water power, derived from considerable falls on the glacier-fed streams. In utilizing a great waterfall and distributing widely cheap mechanical power, the capitalists and engineers at Niagara are helping to solve one of the most interesting and important problems of the present time.

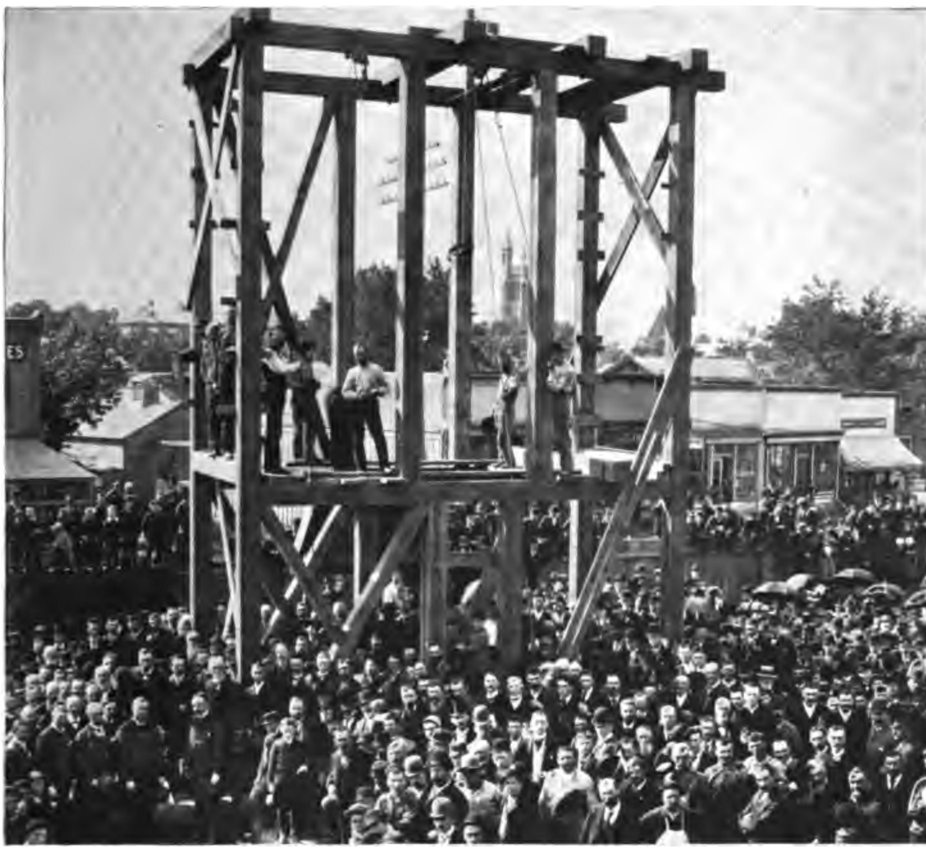


Albert H Porter

Albert Howell Porter was the resident engineer for the Cataract Construction Co. until the completion of the tunnel, and the preliminary work was done under his immediate supervision.

SOME DETAILS OF THE NIAGARA TUNNEL.

By Albert H. Porter, M. Am. Soc. C. E.



OPENING CEREMONIES AT THE BEGINNING OF THE FIRST SHAFT FOR THE NIAGARA TUNNEL.

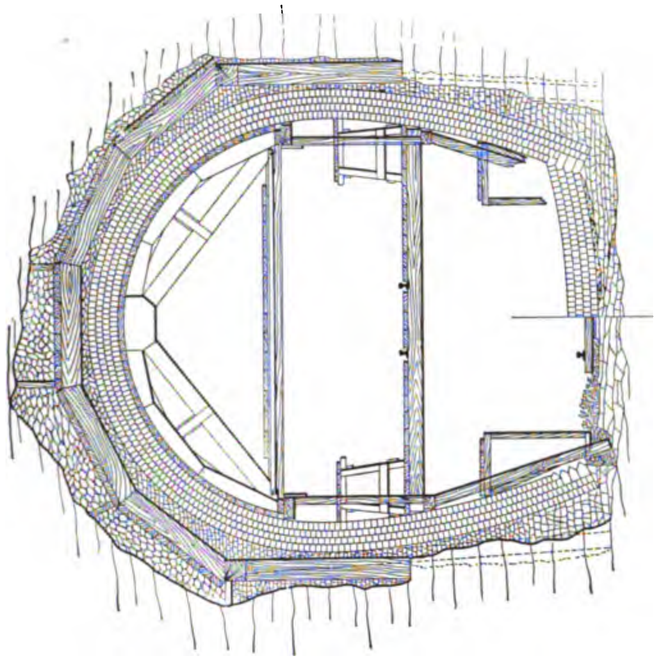
IN the latter part of March, 1890,—a short while ago it seems when one sees the progress made toward the completion of the greatest water power project and enterprise of our time, which has changed Niagara Falls, then only a village, into a thriving city with the eyes of the world upon her,—surveys were commenced of the lands of the Niagara Falls Power Company and Cataract Construction Company, and the location of the great tunnel from these lands, under the village to the river below the Falls, was begun. A right of way had been acquired previous to this, surveys of which were started immediately to see what additional grants would be necessary to locate the tunnel in a straight line, which was desirous for constructional and hydraulic reasons.

This right of way was largely covered

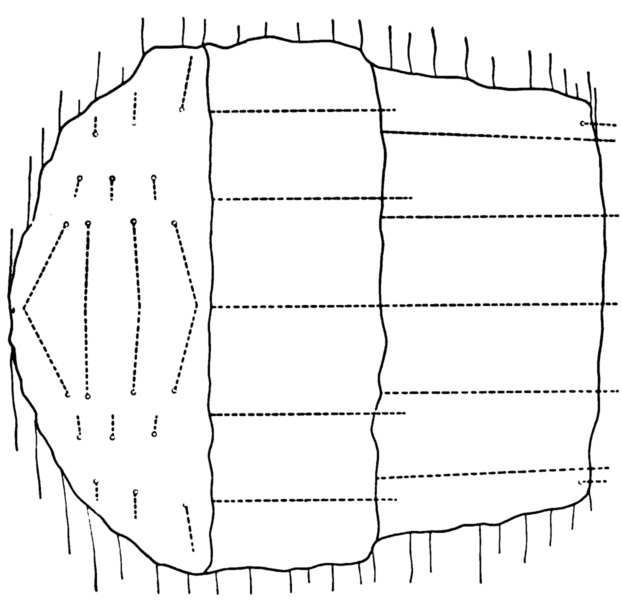
with buildings, and in order to more readily and accurately perfect the surface alignment, a tower was erected just east of the New York Central & Hudson River Railroad depot. The tower was a double one, over fifty feet in height, with three legs to each tower, the inside one being the tripod for the alignment instrument, while the outside one, which was entirely clear of the tripod, in order that there should be no jarring or vibration, had a platform for the engineers to stand on in sighting the instrument. From the top of the tower all buildings could be cleared and a point set in Canada, from which points were thrown back across the gorge to the tunnel portal. Points were also set east of the tower for the shafts and along the line of tunnel. The profile accompanying shows the location of the tower, its use and advantage, and will readily explain the method of alignment.

LOWERING A GIRDER INTO THE WHEEL-PIT.

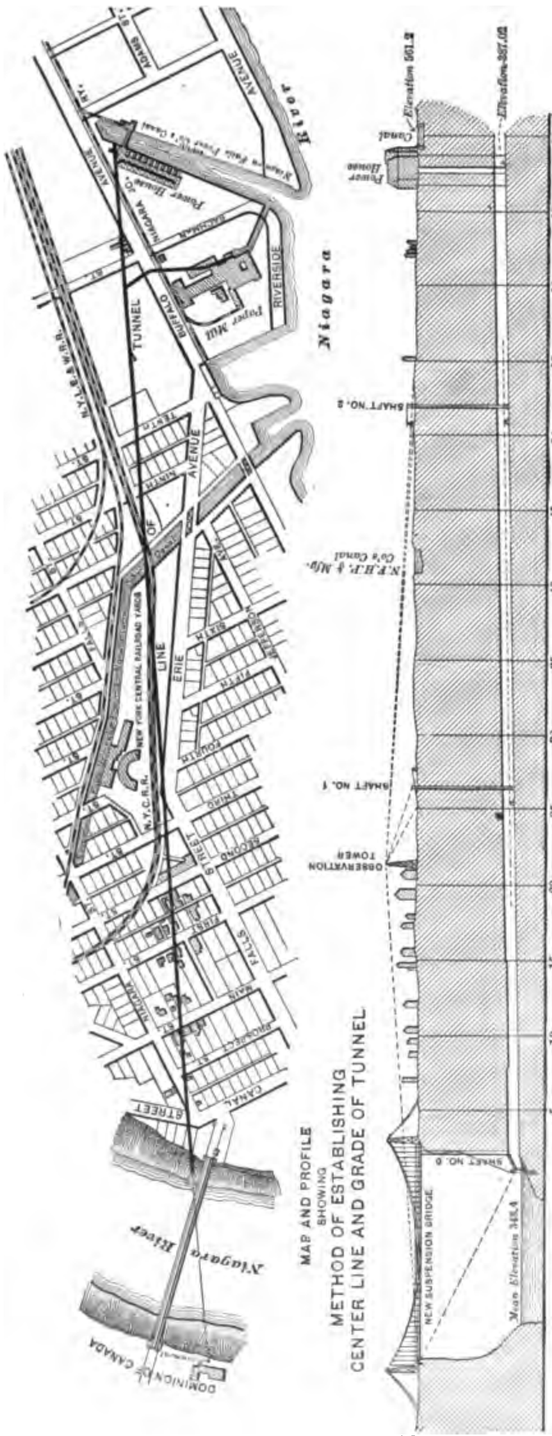
The work of constructing the tunnel was prosecuted from two shafts and the portal in the lower river. There was also a shaft at the portal at the top of the sloping bank to enable a straight lift to the top of the bluff. Shaft No. 1



CROSS SECTION OF TUNNEL, SHOWING METHOD OF LINING.



CROSS SECTION OF TUNNEL, SHOWING POSITION OF DRILL HOLES.



MAP AND PROFILE SHOWING METHOD OF ESTABLISHING CENTER LINE AND GRADE OF TUNNEL

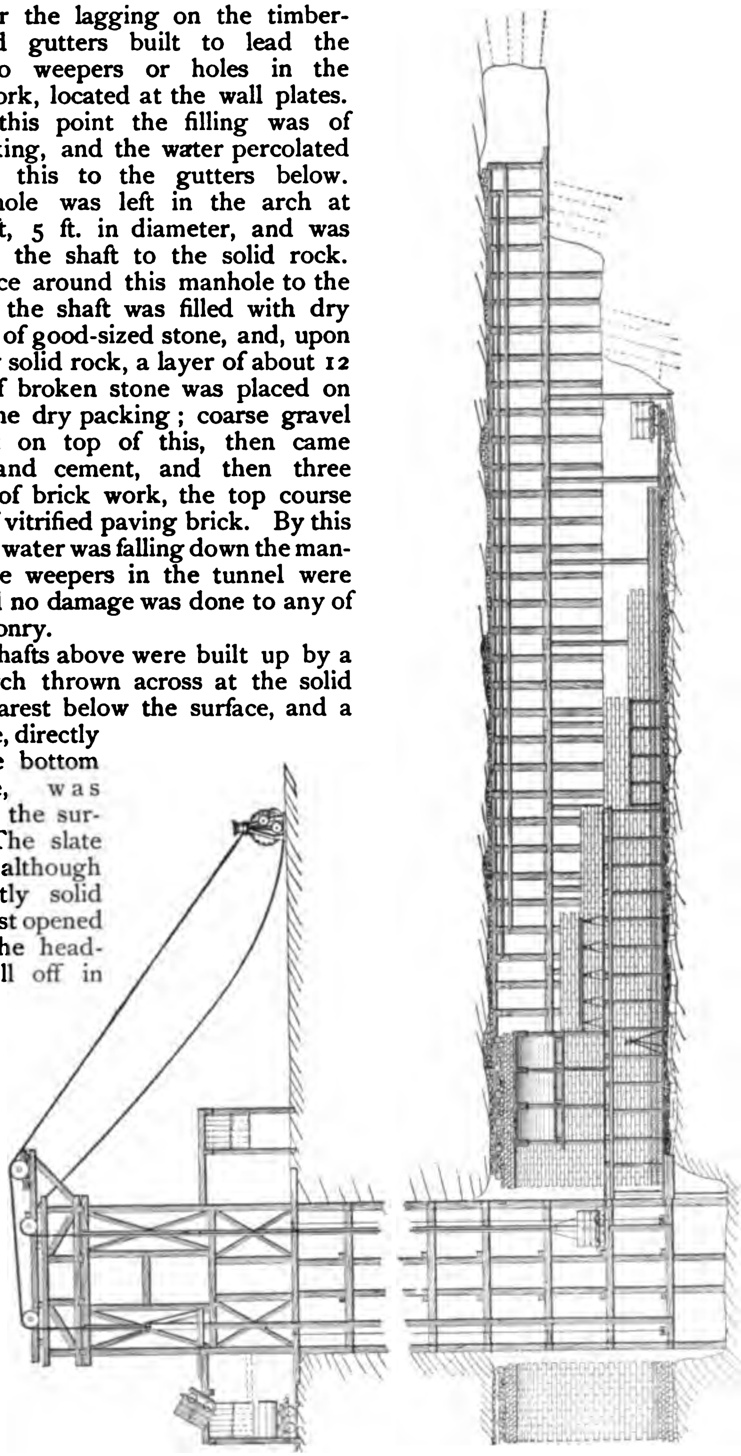
was located 2600 feet, and shaft No. 2, 5200 feet from the portal. Points for diamond drill borings were located along the line of the tunnel, and borings were made at several places. From the results of these borings the profile showing the rock stratifaction was made. From the rock cores taken out by these borings, it was thought that an unlined tunnel could be driven, but after sinking the shafts and driving the headings a short distance, the rock was found to be of such a character that, upon consultation, it was deemed necessary to line the tunnel throughout, not only to make a safe and practical construction, but to have a more perfect tailrace.

The upper stratum, or the Niagara lime-stone, is a hard rock, but is full of seams, through which the water comes in great quantities, and in sinking the shafts this water caused much trouble and greatly increased the difficulties of construction. In order to intercept the water from falling to the bottom, the plan shown in one of the appended illustrations was devised, by which gutters were cut and built around the shafts leading to basins or sumps in the sides of the shafts where pumps were placed and the water was forced to the surface. In shaft No. 1 fully eight hundred gallons of water a minute were pumped.

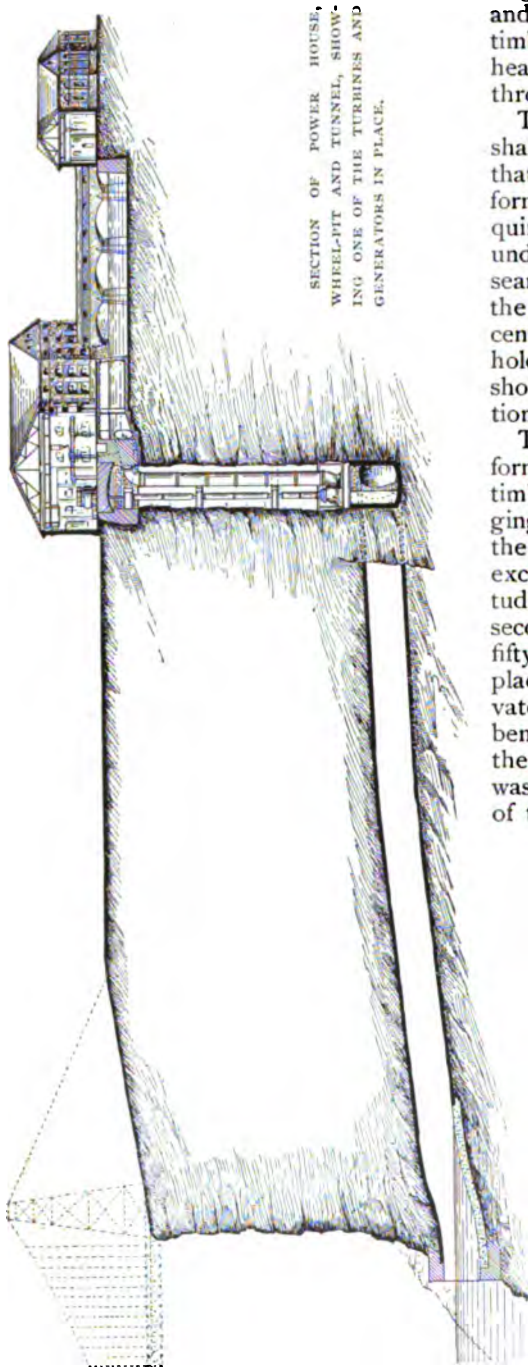
When the brick work of the tunnel was completed and the working shafts were being closed up, the water again caused serious obstacles to the construction of the brick work and masonry. To obviate this, tar paper was

put over the lagging on the timbering, and gutters built to lead the water to weepers or holes in the brick work, located at the wall plates. Above this point the filling was of dry packing, and the water percolated through this to the gutters below. A manhole was left in the arch at the shaft, 5 ft. in diameter, and was built up the shaft to the solid rock. The space around this manhole to the sides of the shaft was filled with dry packing of good-sized stone, and, upon reaching solid rock, a layer of about 12 inches of broken stone was placed on top of the dry packing; coarse gravel was put on top of this, then came gravel and cement, and then three courses of brick work, the top course being of vitrified paving brick. By this time the water was falling down the manhole, the weepers in the tunnel were dry, and no damage was done to any of the masonry.

The shafts above were built up by a brick arch thrown across at the solid rock nearest below the surface, and a manhole, directly over the bottom manhole, was built to the surface. The slate rock, although apparently solid when first opened up in the headings, fell off in



LONGITUDINAL SECTION, SHOWING METHOD EMPLOYED IN SINKING SHAFT, AND TIMBERING, BRICK-LINING AND DRIVING THE MAIN TUNNEL.



SECTION OF POWER HOUSE, WHEEL-PIT AND TUNNEL, SHOWING ONE OF THE TURBINES AND GENERATORS IN PLACE.

large slabs when exposed to the air, and necessitated not only temporary timbering and props in the advance heading, but permanent timbering throughout.

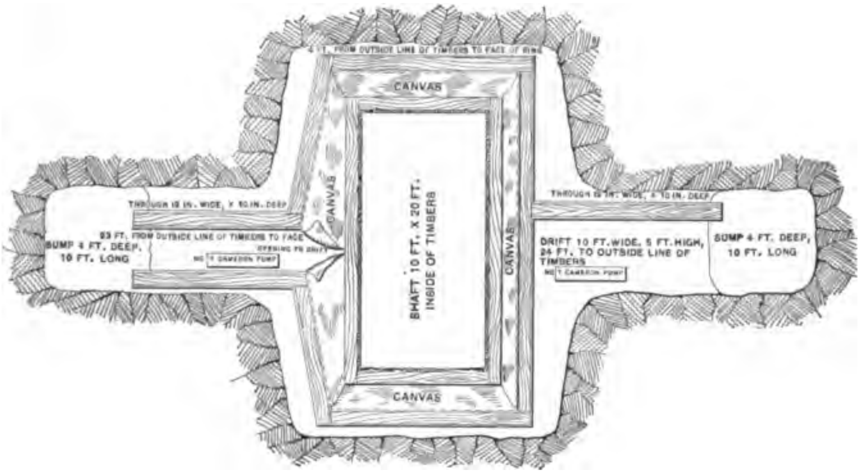
The layer of limestone under the shale was a firm strong rock, and in that portion of the tunnel where it formed the roof, no timbering was required. The sand stone and sand shale under the limestone were full of clay seams. The system of blasting used in the heading was the American, or centre cut method, the location of drill holes for the heading and benches being shown on the accompanying cross section and profile.

The permanent timber arch was formed of five blocks of 12 x 12-inch timbers, covered with three-inch lagging, packed over with dry stone to the rock roof. The first heading was excavated to the bottom of the longitudinal timber or wall plates. The second bench followed within about fifty feet of the heading, posts being placed under the wall plates, as excavated. The heading and first or upper bench were carred along together until the headings met. The lower bench was excavated a short distance ahead of the brick lining. In some cases, on account of the poor rock, it was found necessary to place long posts to the bottom of this bench to support the wall plates.

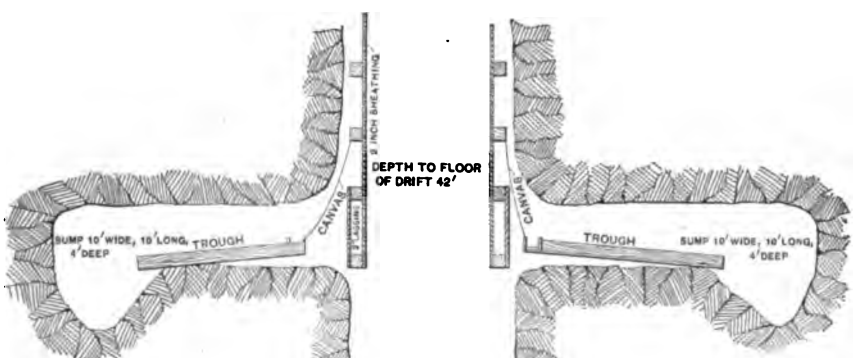
The best progress made in any heading during the construction of the tunnel was 94 feet in one week. The best progress for the five headings was 331 feet in one week, an average of over 66 feet to each heading, and the same week 321 feet of the first bench were taken out and the timbering was carried along. The brick work was built in the different sections, as shown on the profile and plan.

The brick side-walls were built first, a specially formed brick being used where the invert or bottom joined on. The invert was the last brick work to be laid in the tunnel. For setting these

side-walls a templet or form was set on correct grade and line. This was made, as shown in the section, with notches cut for the special brick and saw cuts made for each course of brick. Above these the centres were set which were



PLAN SHOWING ARRANGEMENT OF TROUGH AND CANVAS.



SECTION THROUGH CENTRE OF DRIFTS.

PLAN ADOPTED FOR HANDLING WATER AT SHAFT NO. 2.

especially adapted to the arrangement of scaffolding and the method of handling material used, which are shown on the cross and longitudinal sections. The spaces between the brick work and the rock and around the posts were all filled with rubble masonry up to the haunch of the arch. Above this and over the brick arch dry packing was used.

On the accuracy of alignment and grade depended the meeting and outcome of all the different steps described above. The alignment in the tunnel was produced from two small steel piano wires suspended from the surface with 30 lb. flanged plumb bobs, hanging in buckets filled with oil. These wires were on movable screws on the surface, and were kept on the true line with a transit instrument about 30 or 40 feet from the shaft. The distance between the wires was about 17 feet. From these wires at the bottom a transit instrument was sighted and worked on to the true line and points

set in the tunnel. This was repeated three times, or until the result proved satisfactory.

The elevations were established at the bottom of the shafts by means of a long accurately tested steel tape, kept on a known elevation on the surface by means of a level instrument, and read at the bottom by another level from which the elevations were established on bench marks of iron bolts, secured in the rock. This was also done three times, or until a satisfactory result was obtained. The result of the alignment and grade of the tunnel was most satisfactory, as there was no deviation or error in all the construction, and no work had to be changed or torn out. The clearance allowed between the timbering and brick work was only 4 inches, the smallest in any tunnel.

The tunnel shafts were started late in September, 1890. The tunnel for a length of 6700 feet was entirely completed in January, 1893, and the final estimate for the contract of the main tunnel was made in March, 1893. The material excavated from the tunnel was used to fill up the lands under water acquired by the company, a small railroad being built from shafts Nos. 1 and 2 for that purpose. To-day the greater part of the plant of the Niagara Falls Paper Mill stands on land which was then mostly all under the water of the Niagara River.

During the summer and fall of 1890, contour surveys of the lands and river adjoining them were made, and from these the best entrances from the river, location of the canal, wheel-pits, etc., were determined upon by the engineers.

GEORGE BARKER BURBANK was the resident consulting engineer of the Cataract Construction Co. during the period covering probably the most important part of the work, and later was chief engineer. His article here embraces the first official statement ever made regarding it.

THE NIAGARA FALLS POWER COMPANY'S STATION.

THE CONSTRUCTION OF THE NIAGARA TUNNEL, WHEEL-PIT AND CANAL.

By George B. Burbank, Mem. Am. Soc. C. E.

IN the latter part of May, 1891, the writer was called upon by the Cataract Construction Company to examine and report as to the necessity of lining the main tunnel of the Niagara Falls Power Company at Niagara Falls. At that time, under the direction of Resident Engineer Albert H. Porter, the shafts had been sunk to the tunnel level, and headings had been driven for 50 to 75 feet from the shafts.

In these headings the material to be encountered while driving the tunnel was fully developed. An argillaceous shale was found which, upon exposure to the air, crumbled away, necessitating prompt support with timber to avoid serious falls from the roof. After an extended examination of all the workings, it became clearly evident to me that lining with brick throughout was an absolute necessity, and that timbering would also be required for the entire length of the tunnel, with the possible exception of a distance of about 800 feet where a ledge of limestone, eight feet in thickness, could be utilized for the roof.

My report was rendered in accordance with these findings, and the subsequent construction fully confirmed the correctness of the recommendations. After making this report, and assisting in the remodeling of the construction contracts, I was invited to supervise the work, as resident consulting engineer, and, resigning my connection with the New York Aqueduct, I became established in that capacity at Niagara Falls early in the month of June. Upon the completion of the tunnel to the 6700-foot station, in January, 1893, I became chief engineer of the work, and of the companies allied to the Cataract Con-

THE TUNNEL DURING CONSTRUCTION.

struction Company, and continued in that capacity until the completion of construction in 1894. After the decision in regard to lining was made, the tunnel work was vigorously prosecuted by the contractors, until its completion, under the special supervision of Resident Engineer Porter and Division Engineer Mr. William S. Humbert.

The tunnel is lined throughout with at least four rings of the best hard-burned brick, making a solid brick wall sixteen inches in thickness. At points where, from the nature of the material through which the tunnel was driven, it was thought possible that greater strength might be required, the thickness was increased to six and even eight rings.

The upper or face ring of the invert was laid with the best quality of vitrified paving brick. All spaces between the brick work and sides or roof of the tunnel were filled with rubble masonry. American Portland cement was used exclusively for mortar in laying brick and stone masonry in the tunnel and wheel-pit. The composition of the mortar generally used was one part cement to three parts sand, but at the shafts and the wheel-pit, where the flow of water was very strong, the proportion was changed to one to two, and in some cases one to one. This bricking commenced in March, 1892, and followed the work of excavating as closely as was consistent with safety.

ONE OF THE CANAL INLETS AT AN EARLY STAGE.

A very satisfactory method of lining the arch was adopted. The main feature was the construction of a platform about ten feet above the invert after the side walls were laid to as high a point as was convenient for the handling of brick and mortar. On this platform tracks were laid, and the brick and mortar were hauled to their destination, a separate landing being made in the shafts at the proper elevation. The great advantage of this system consisted in enabling the contractors to carry on the work of ex-

LOWERING A PENSTOCK INTO THE WHEEL-PIT.

cavating and of lining at the same time, without the possibility that the outgoing cars, loaded with material excavated in driving the tunnel, could interfere with cars coming in, loaded with brick and mortar, the brick work, at times, being carried on within less than 100 feet of the face of bench excavation in the tunnel.

At the portal it was decided to drop the grade of the invert about eleven feet below the average low water of the river thus permitting fully one-half the flow from the tunnel to discharge below the surface. To this end, the grade was changed into an ogee commencing at a point 90 feet from the portal, dropping nearly eleven feet in that distance.

This portion of the tunnel, to the elevation of the spring line, was lined with steel boiler plate, riveted to steel ribs three to four feet in depth, which were bedded solidly in Portland cement concrete, the arch being turned with brick except for 25 feet at the portal, where the construction was granite masonry. The masonry for this facade was carried solidly to a depth of 38 feet below the surface of water, when a ledge of white sandstone was struck, which was entirely satisfactory for a foundation.

The first contract was with Messrs. Rodgers & Clement, of New York City, for 6700 feet of tunnel with two main shafts and a smaller shaft at the bluff near the portal. This contract was completed in January, 1893. On January 5, 1892, a contract was made with A. C. Douglas, of Niagara Falls, for an extension of the main tunnel 300 feet further, making a total length of 7000 feet in main tunnel; for a tunnel connection of same size to the wheel-pit, and for the wheel-pit, and for a short tunnel, circular in shape and ten feet in diameter, providing for a possible development of lands owned by the company on the north side of the tunnel.

The wheel-pit, which is really an elongated shaft, is an uncommon feature in construction, particularly in its magnitude. The dimensions are: Length, 140 feet; width, 18 feet; depth, 178 feet. This pit is lined on the bottom with 16 inches of brick, the top course being of best quality paving brick, and

on the sides, to the height of 30 feet above the invert, with from two to two and a half feet of solid brick masonry. This wall is capped with a single course of limestone, two and one-half feet in thickness, on which the girders, weighing about twenty-five tons, are placed. These carry the weight of the penstocks and turbines, of 5000 horse-power each. It is intended ultimately to extend this wheel-pit to a length of about 400 feet.

The masonry construction of special interest is at the connections between the main tunnel and the side tunnels, and at the portal or place of discharge into the lower river. First in importance is the connection between two horseshoe arches, each 21 feet high and 18 feet 10 inches wide at the spring line, at an angle of 60 degrees; and second, the connection between a circular arch 10 feet in diameter and the horseshoe arch, also at an angle of 60 degrees. All designs and details for the connections were prepared by Mr. George F. Simpson, the chief draughtsman in this de-

THE MOUTH OF THE TUNNEL DURING CONSTRUCTION.

partment of the work. The Brandywine Granite Company, of Wilmington, Del., furnished all granite in this construction, cut into shape and to the dimensions required. The arches for the connection with the tunnel were laid by the contractor under the direct supervision of Mr. J. G. Tait, assistant engineer, who found all preparatory work so accurately done that practically no difficulties were encountered, except such mechanical ones as would naturally be expected in constructing arches of that massive character in tunnels, allowing an average clearance not exceeding one foot.

In August, 1891, work had been commenced, with a company force under the direct management of myself, on the main and inlet canals. The mouth of the canal is 600 feet from the shore line, necessitating the construction of embankments on each side for that distance into the river. After these embankments had been extended to the proper places, a coffer dam, 450 feet in length, was thrown across the mouth and connected with the ends of these embankments. This coffer dam was constructed with two lines of crib-work filled with stone, the outer one 12 feet in width, the inner one 10 feet in width, with an intervening space of 8 feet, which was carefully lined on each side with sheet piling. After the piling was completed, the loose and sandy material was removed to a hard clay bottom by the use of a centrifugal pump, and the space was then filled with clay which was dumped into the water and worked as much as possible. This dam was practically water-tight and remained in perfect condition until removed in the spring of 1894. One leak, which gave trouble for several hours, was due to an imperfect connection with the side dump from the shore at the east end of the dam. No delay in the work of excavation or of laying masonry was, however, experienced from this cause.

A PROGRESS VIEW OF THE CANAL.

The side walls of the canal are of solid masonry, 17 feet high, 3 feet thick at the top and about 8 feet at base. This work was laid in ordinary American cement mortar, composed of one part of cement and two parts of sand. The excavation and masonry were carried on simultaneously, and the canal was

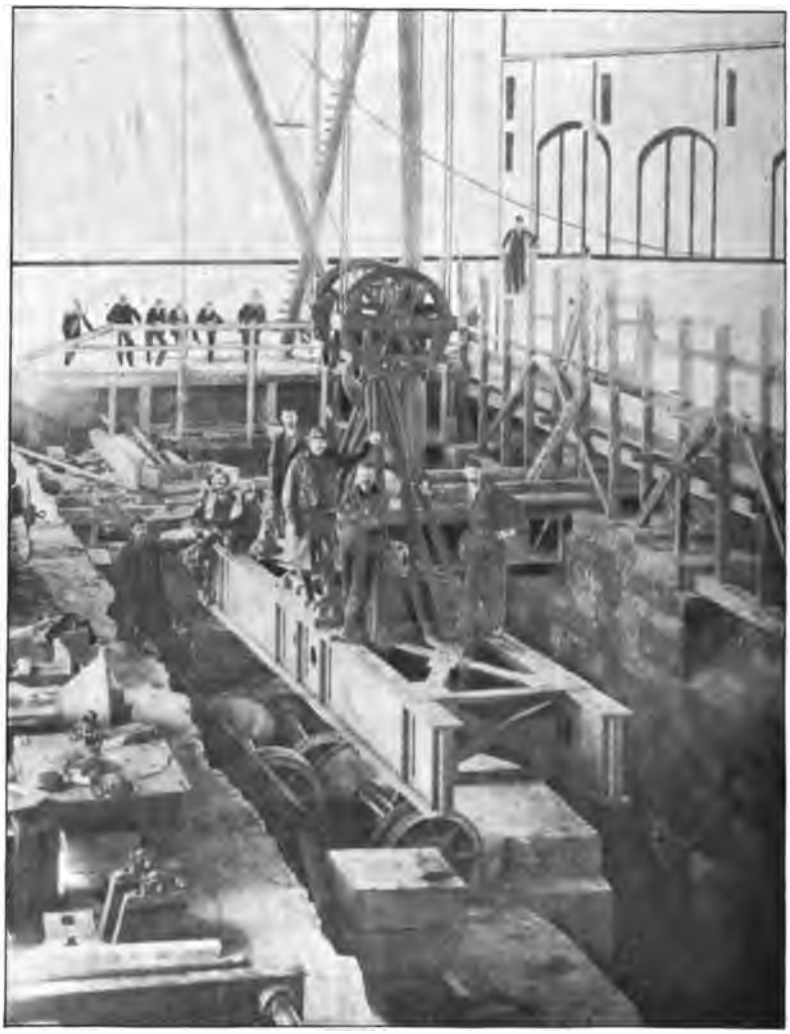
ANOTHER EARLY VIEW OF THE TUNNEL'S MOUTH.

A VIEW OF THE WHEEL-PIT DURING CONSTRUCTION.

A TUNNEL VIEW, SHOWING THE METHOD OF LINING WITH BRICK.

completed in October, 1892. The canal carries twelve feet depth of water at the ordinary low stage of the river.

During the year 1892–93, the Niagara Junction Railway was constructed, which runs through the entire length of the property owned by the various corporations allied in interest. This railway connects with all the trunk lines, and extensive docks have been constructed on the Niagara River, on which its rails are laid, making connection with the traffic of the Great Lakes. By this railway, materials and freights are received from, and delivered to, all the manufacturing sites which this development opens to the public. During the same time a new water-works plant was established with a capacity of 6,000,000 gallons per day, the water being taken from the Niagara River one mile above the falls.



GETTING READY FOR THE TURBINES.

A LATERAL TUNNEL JUNCTION.

Accommodations have also been provided for operatives, by the erection of 50 handsome and convenient cottages, with fine macadam streets, a complete system of drainage and sewerage, with disposal works and unlimited water supply. Of this work, as well as of the water-works and railway construction, Division Engineer Mr. William A. Brackenridge was in special charge.

A handsome power house has been completed over the wheel-pit, after designs by Messrs. McKim, Mead & White, of New York City, the contractors being Messrs. James Stewart & Co., of St. Louis and Buffalo. The outer surface is of limestone, and the inner, for a height of six feet from the floor, is of enameled brick, and above that of ordinary brick, coated with white enamel paint. In this building, which is 200 feet in length, a 50-ton traveling crane transferred the machinery for the turbines from the cars to their location in the wheel-pit. The greatest number of men employed at any one time was about 2500. In the construction 600,000 tons of material were removed, and there were used 16,000,000 bricks, 19,000,000 feet of timber and lumber, 60,000 cubic yards of stone, 55,000 barrels of Giant American Portland cement, 12,000 barrels of natural cement and 26,000 cubic yards of sand.

Clemens Herschel

CLEMENS HERSCHEL was consulting hydraulic engineer of the Cataract Construction Company during the period of construction.

NIAGARA MILL SITES, WATER CONNECTIONS AND TURBINES.

By Clemens Herschel, Hydraulic Engineer.


ONE of the present series of articles must evidently treat of the power producing plant, and its installation,—two essential elements in the series of mechanisms that convert the flow of the Niagara river over the Falls, into other forms of energy,—finally represented by a revolving shaft in the factory, by the speeding car in the street, or by other of its manifold forms of utility. It is this part of the description of the manner of utilizing Niagara Falls that is to fall to the lot of the present article.

The standard American method of utilizing a large amount of water-power, has hitherto been, to distribute the water to the several consumers, or mill-owners, by means of a system of head-races, so-called, with facilities for its discharge at a lower level, to be utilized as the owner or lessee saw fit, and generally on his own premises. This led to long head-canals, and to insignificant tail-races, whereas, as we shall presently see, the Niagara plant consists of a common tail-race, a mile and a half long, with comparatively insignificant head-races. The old-time water-power company sold or leased the right to draw

BY SPECIAL ARRANGEMENT WITH DR. F. P. VAN DENBERGH, BUFFALO, N. Y.

EYE VIEW AND SECTION OF THE NIAGARA INSTALLATION.

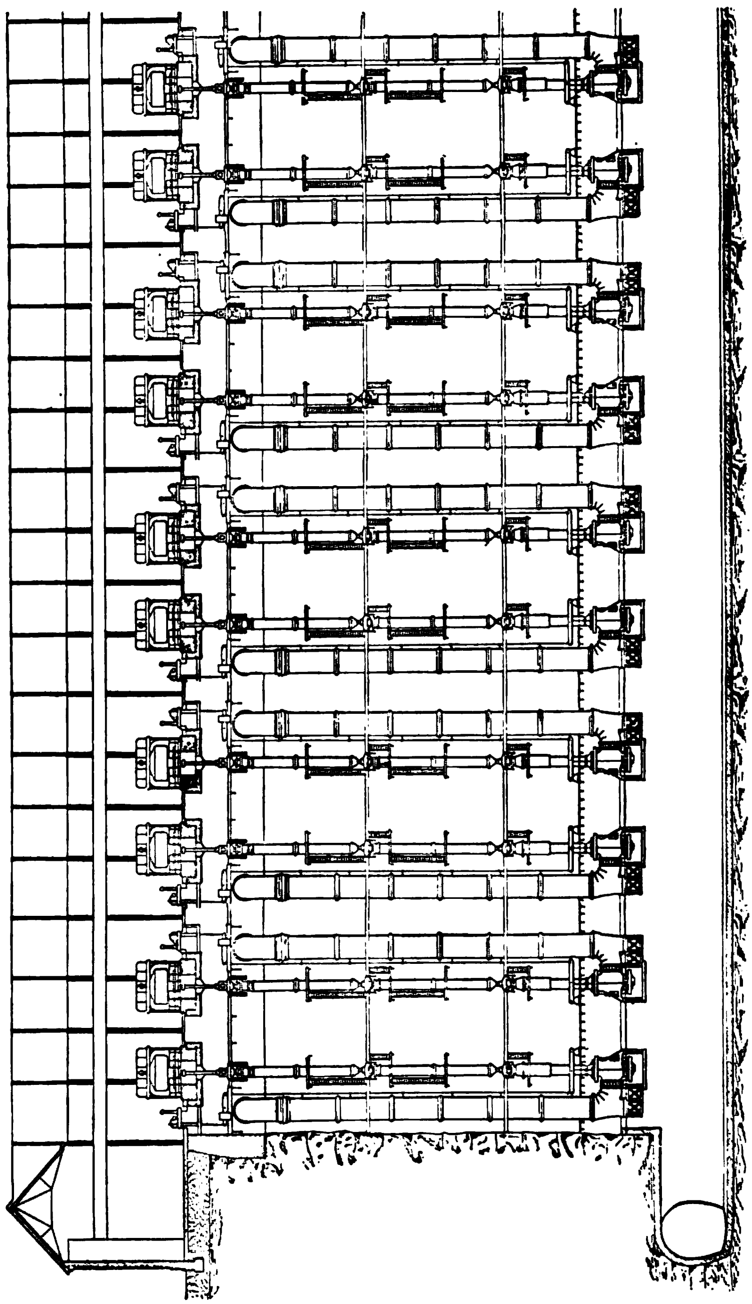
a definite quantity of water, at defined times, with the privilege of discharging it at a lower level, and the mill-owner did the rest; whereas, at Niagara Falls, the right is leased to discharge a definite quantity of water into the tail-race tunnel, with the privilege of drawing this quantity from the head-canal, or from the river. But over and above this the product,—power,—may be contracted for at Niagara Falls, delivered on the shaft.

To create a large group of mill-sites of the older sort, there was necessary, in the first instance, a large continuous body of land, properly located for the purpose. If this could not be bought up secretly, and in large blocks, the whole water-power enterprise would fail to come to fruition. In Europe, however, several such enterprises came into being in spite of the inability of the projectors to primarily buy tracts of land such as have been described. This was done by establishing central power stations near the dam, or head canal, and then transmitting the power produced, instead of the water to produce it, to the consumers, or mill-owners. Up to within say five years, this had always been accomplished by means of wire-rope transmissions of power, and it is easy to see that the inve: tion of the electrical transmission of r :r would give this form of the : tion of large water-power a impetus. Many such plants are, fore, already in existence, many uilding, but among them all, no probably so celebrated, and is at- ng the attention of all intelligent men as this at Niagara Falls.

The work at Niagara Falls is designed to be utilized in both of the methods above described, and examples of both methods of distributing power are built. The plant of the Niagara Falls Paper Company is an example of the first and old r method of power utilization, while th tral Power Station of the Niag. 'alls Power Company is the granu st example yet undertaken of the second described, and the later method of power distribution. The Niagara Falls Power Company also owns some 1200 acres of land adjoining the Cent Power Station and the present heac car. all of which can be utilized for the s es of manufacturing establishments by one or the other of the methods described. This has been l: l out in streets and blocks, with a freight railroad, to be spoken of presently, connecting the mill sites with all the trunk lines that pass Niagara Falls, and adjoins the residential district being developed by the Niagara Development Company, whose first fruits are the village called Echota, and the adjoining wharf and other property. But over and beyond all this, a transmission of power to Buffalo, only 20 miles off, and possibly still further, is within the scope and design of the Central Power Station now building.

It is interesting to find how the work of to-day was dream f in 1876. In that year the late Sir liam Siemens came to America to see the Centennial exhibition. Proceeding to Niagara Falls, he was struck with its capabilit as a power-producing centre, and carried out what was probab the first computation ever made c cost of distributing power from N a Falls to the country around it by ctricity. In the "Life of Sir William Siemens," by William Pole, this subject is ted at length, and the following o from it may be interesting in

"When such a machine a namo was once ought into exist t was sure to b en advantage other applicatio of owerful e. c energy. * * * I ecessary to allude to one kable case ich was amon arliest to wh r. Siemens is attention. the electric ent is used, not fo n of its own, but merely as a vehic. or the transmission of power; just as a boat on a river, or a wagon on railway is used to transport some val le commodity for use at a distant p. The power of horses, or of a wa l, or of a steam engine, is applie dynamo to excite a current; th nt is passed along a wire, and wi , the aid of another dynamo at the other end of the wire, reproduce the power (or a

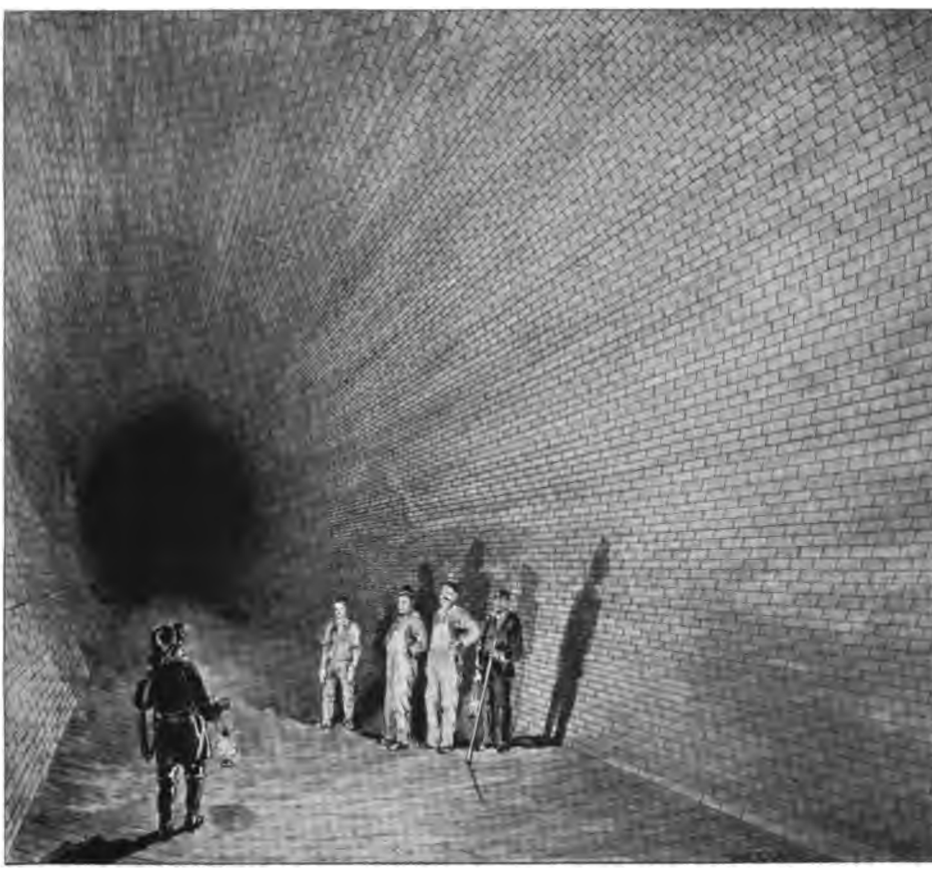


SECTIONAL ELEVATION OF THE POWER HOUSE AND WHEEL-PIT OF THE NIAGARA FALLS POWER COMPANY, TO CONTAIN TEN 5000 HORSE-POWER ELECTRIC GENERATORS AND TEN 5000 HORSE-POWER TURBINES.

portion of it) in a far distant locality.

"This use of electricity formed a favorite study for Dr. Siemens, and it seems to have first strongly impressed itself on his mind when, in the autumn of 1876, he went to America and visited Niagara Falls. In all his many journeys in different countries nothing made such a deep impression on him as this wonderful natural phenomenon. The stupendous rush of waters filled him with fear and admiration, as it does every one who comes within the sound of its mighty roar. But he saw in it something far beyond what was obvious to the multitude, for his scientific mind could not help viewing it as an inexpressible manifestation of mechanical energy. And he at once began to speculate whether it was absolutely necessary that the whole of this glorious magnitude of power should be wasted in dashing itself into the chasm below—whether it was not possible that at least some might be practically utilized for the benefit of mankind?

"He had not long to think before a possible means of doing this presented itself to him. The dynamo machine had just then been brought to perfection, partly by his own labors; and he asked himself, why should not this colossal power actuate a colossal series of dynamos, whose conducting wires might transmit its activity to places miles away? This great idea, formed



IN THE MAIN TUNNEL.

amid the thunderings of the cataract, accompanied him all the way home, and was meditated on in the quiet of his study. He submitted it to the test of mathematical calculation, and so far convinced himself of its reasonable nature, that he determined, when a fitting occasion arrived, to make it known.

"The opportunity arrived in the spring of 1877, when he had to give an opening address as president of the Iron and Steel Institute. In that address he had to point out the dependence of the iron and steel manufacture on coal as a fuel. He alluded to the gradual diminution of the stores in the earth of this valuable commodity, owing to the vast consumption of it for steam-power, and he urged that other natural

THE GENERAL POWER PLAN.

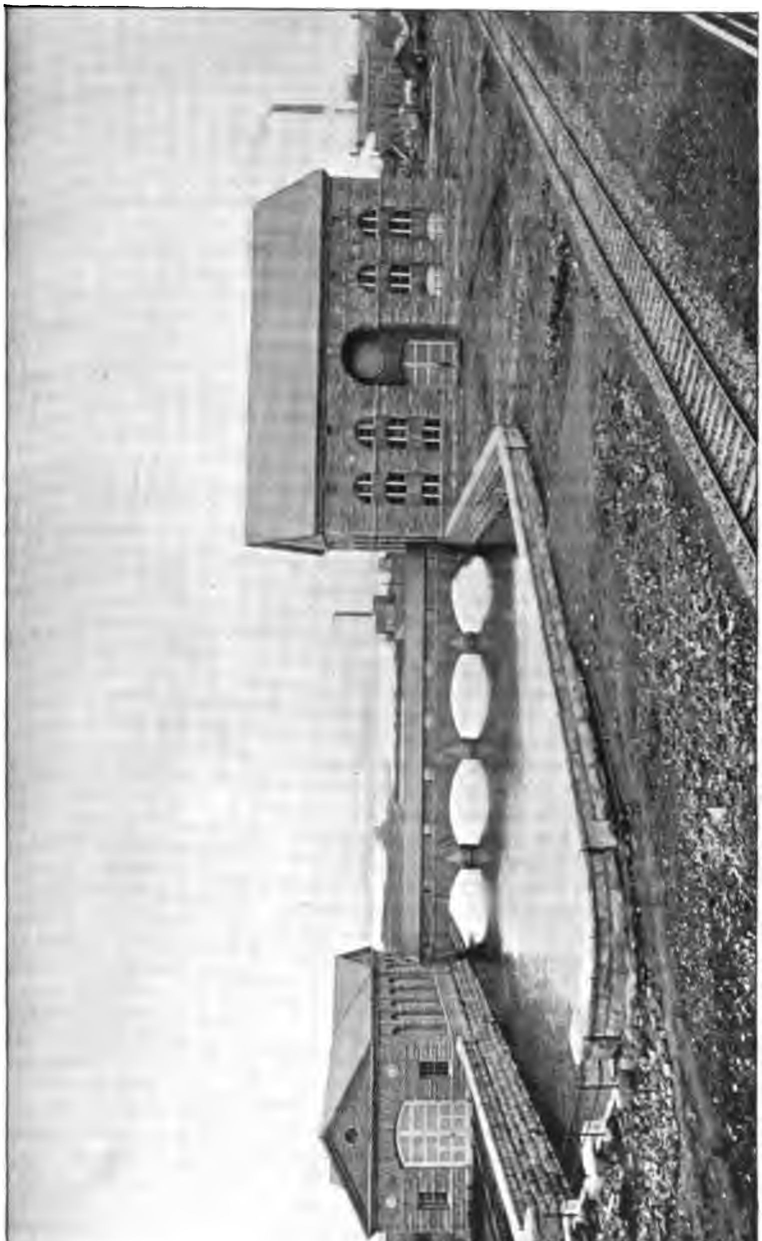
sources of force, such as water and wind, ought to be made more use of. And speaking of water-power, he made the following remarks:

"'The advantage of utilizing water-power applies, however, chiefly to Continental countries, with large elevated plateaus, such as Sweden and the United States of America, and it is interesting to contemplate the magnitude of power which is now for the most part lost, but which may be, sooner or later, called into requisition. Take the Falls of Niagara as a familiar example. The amount of water passing over this fall has been estimated at 100,000,000 of tons per hour, and its perpendicular descent may be taken at 150 feet, without counting the rapids, which represent a further fall of 150 feet, making a total of 300 feet between lake and lake. But the force represented by the principal fall alone amounts to 16,800,000 horse-power,* an amount which, if it had to be produced by steam, would necessitate an expenditure of not less than 266,000,000 tons of coal per annum, taking the consumption of coal at 4 pounds per horse-power per hour. In other words, all the coal raised throughout the world would barely suffice to produce the amount of power that continually runs to waste at this one great fall.

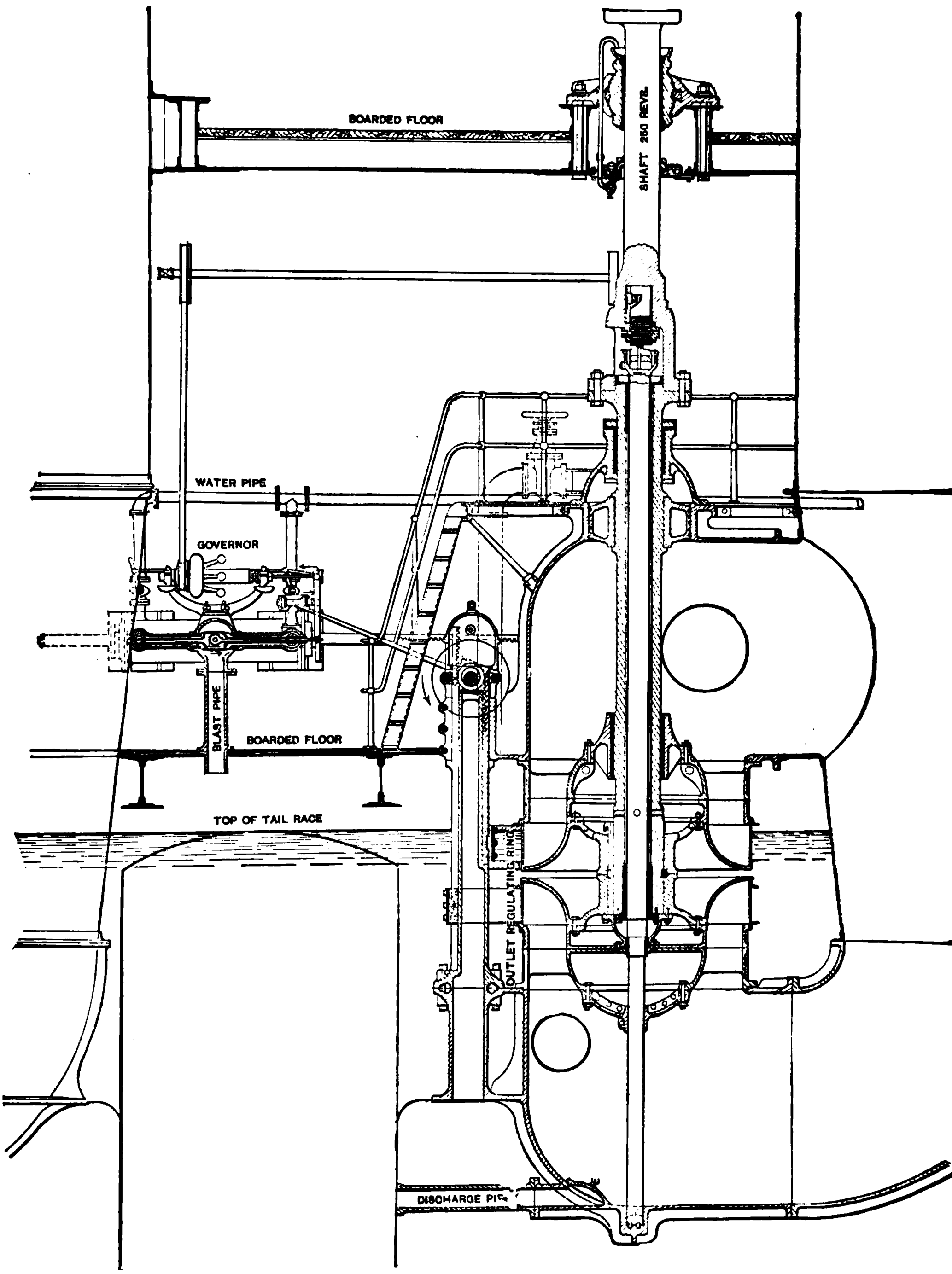
"'It would not be difficult, indeed, to realize a large portion of the power so wasted, by means of turbines and water-wheels erected on the shores of the deep river below the falls, supplying them from races out along the edges. But it would be impossible to utilize the power on the spot, the district being devoid of mineral wealth, or other natural inducements for the establishment of factories. In order to render available the force of falling water at this and hundreds of other places similarly situated, we must devise a practicable means of transporting the power. Sir William Armstrong has taught us how to carry and utilize water at a distance, if conveyed through high-pressure mains, and compressed air has been employed for the same purpose. At Schaffhausen, in Switzerland, as well as at some other places on the Continent, power is conveyed by means of quick-working steel ropes passing over large pulleys; by these means it may be carried to a distance of one or two miles without difficulty.

"'As regards electrical transmission, suppose water-power be employed to give motion to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance, through a large me-

* The gaugings of the United States government engineers give an average discharge of about 275,000 cubic feet per second, which, with a fall of 216 feet, —the difference of elevation between the water above the rapids and that of the lower river—gives a total of 6,750,000 theoretical H.-P.—THE EDITOR.

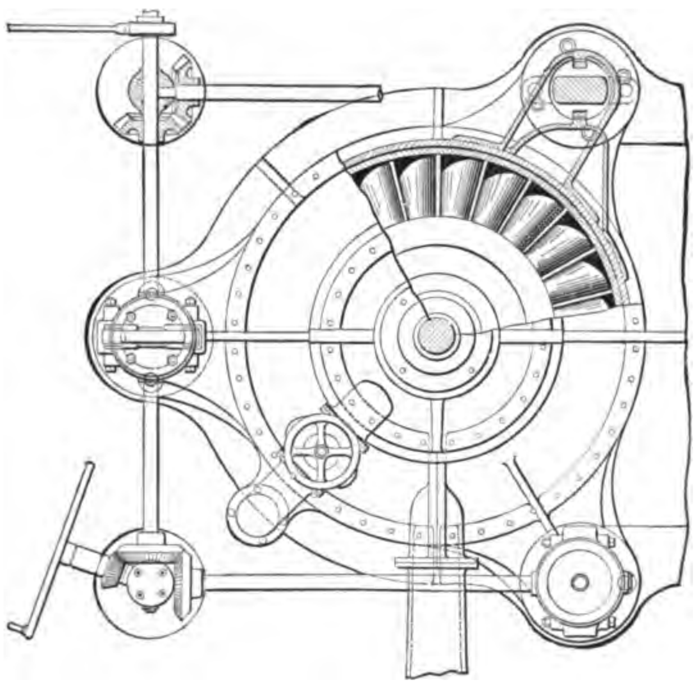


THE MAIN POWER STATION AND THE TRANSFORMER HOUSE, WITH CONNECTING BRIDGE.



SECTION OF WHEEL AND GOVERNOR DESIGNED BY ESCHER, WYSS & CO.

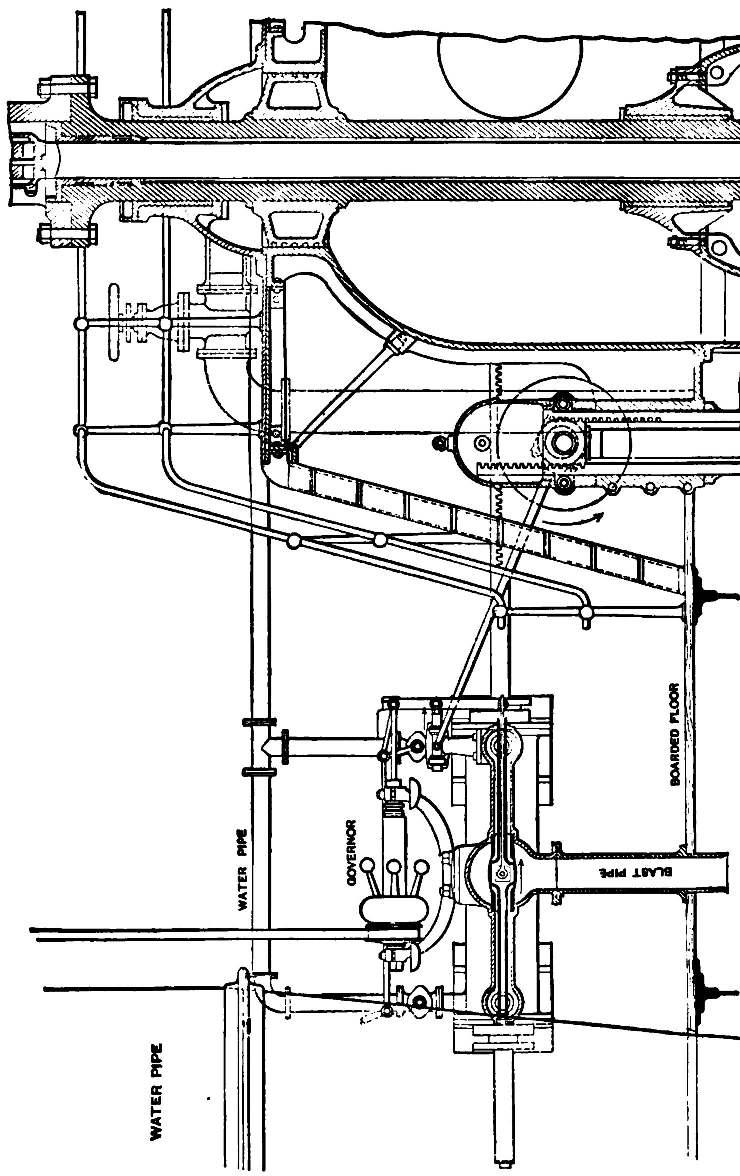
tallic conductor, and then be made to impart motion to electro-magnetic engines, to ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod, three inches in diameter, would be capable of transmitting 1000 horse-power a distance of, say, thirty miles, an amount sufficient to supply one-quarter of a million candle-power, which would suffice to illuminate a moderately sized town.' This statement startled the audience considerably; and it is still remembered that, when it was delivered, a smile of incredulity was observed to play over the features of many of his hearers."



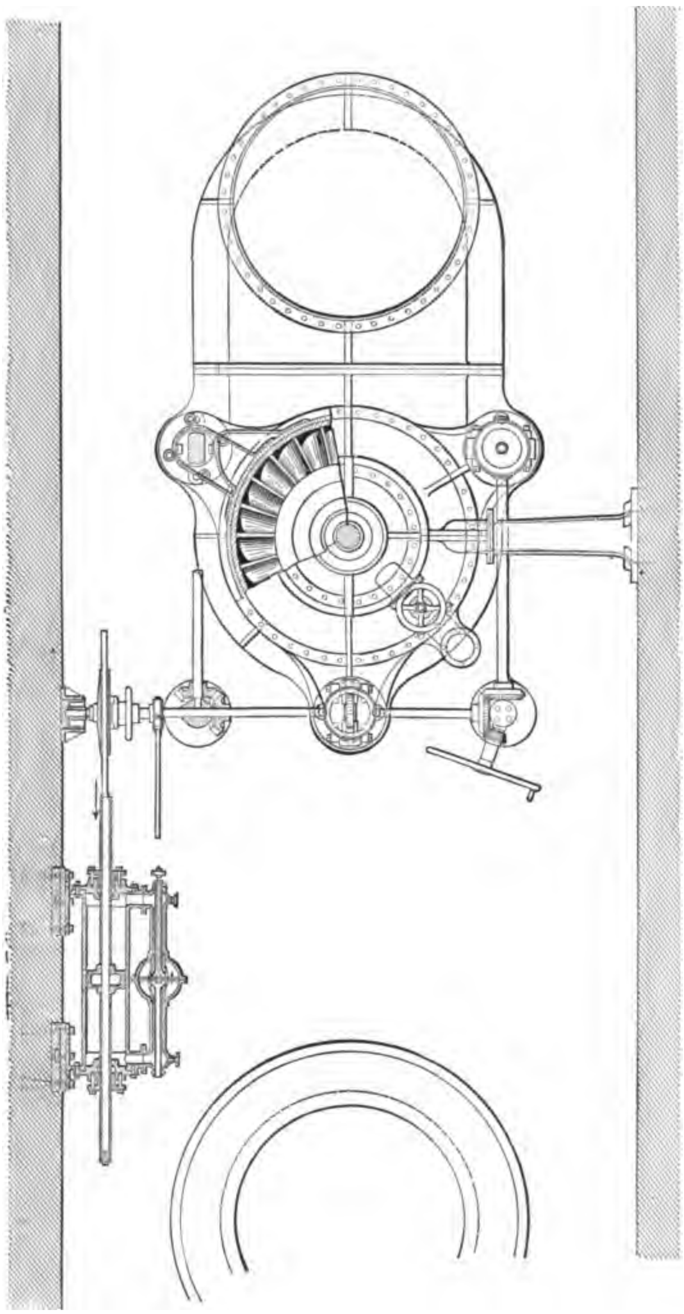
SECTION AND PLAN OF ESCHER, WYSS & CO.'S WHEEL.

One of the neatest and r ~~st valuable attributes of the Niagara F Power Company's mill sites is the roa the Niagara Junction Railway Compa. , Niagara Falls is already, or is destined to be, one of the great railroad centres of the United States. Two railroad bridges cross the river there, each used by several East and West trunk lines, and other such bridges are already talked of. Railroad freight rates are in competition with each other, and with lake and canal rates, and are to-day no greater from Niagara Falls to New York and to Boston, than they are from the established manufacturing centres of the East to these cities, while they are, on the other hand, very materially less from Niagara Falls to the great cities of the West, Southwest and South than they are from these same older manufacturing centres. The present favorable conditions will bring more manufacturing into the Buffalo and Niagara Falls district, and, as such things always operate, will also bring in still other trunk lines of railroad.

It is for the purpose of enabling the occupant of any mill-site of the Niagara Falls Power Company to receive cars shipped to him by any line of railroad entering the Buffalo-Niagara Falls district, and of delivering cars directly to any such railroad, that the Niagara Junction Railway Company was organ-



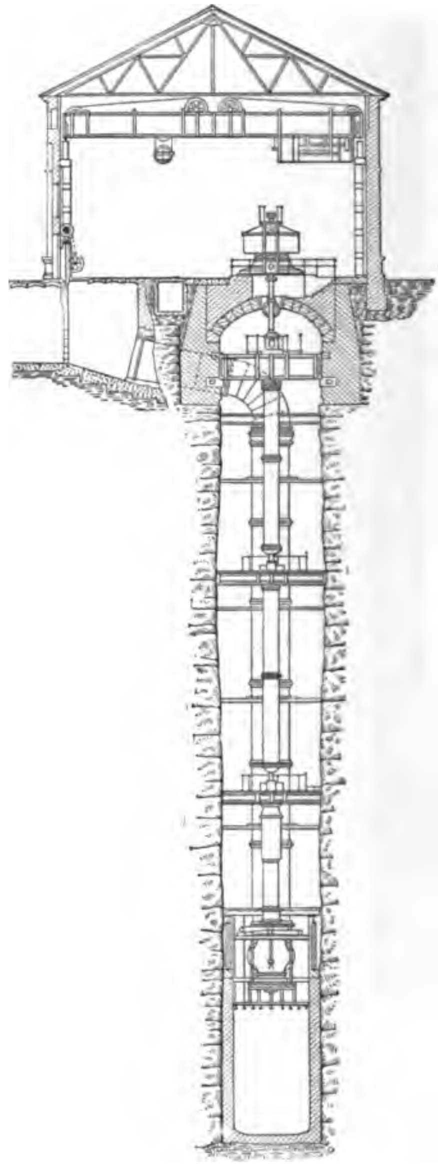
SECTION OF GOVERNOR DESIGNED BY ESCHER, WYSS & CO.



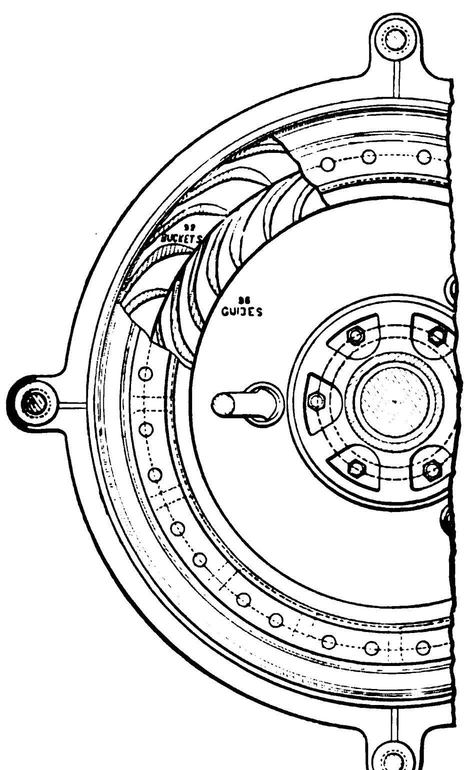
ANOTHER PLAN OF THE WHEEL DESIGNED BY ESCHER, WYSS & CO.

ized and the road built. It is an allied enterprise of the Niagara Falls Power Company and will do no little in furthering the growth and business of the new city, benefiting, in turn, all the trunk lines that do now or will, eventually, traverse the Niagara Falls neck of land between Lake Erie and Lake Ontario. Lake transportation, and transportation on the Erie Canal are, however, also available to the occupants of these mill-sites. Many of them front directly on the Niagara river, where it is navigable, and none of them are any great distance from it.

It will not be necessary to say much more on the subject of water connections at the Niagara mill-sites. The Niagara Falls Paper Company has a square wheel-pit, which is connected with the main tunnel tail-race by a branch tail-race, 7 feet in diameter. All dimensions of underground work are

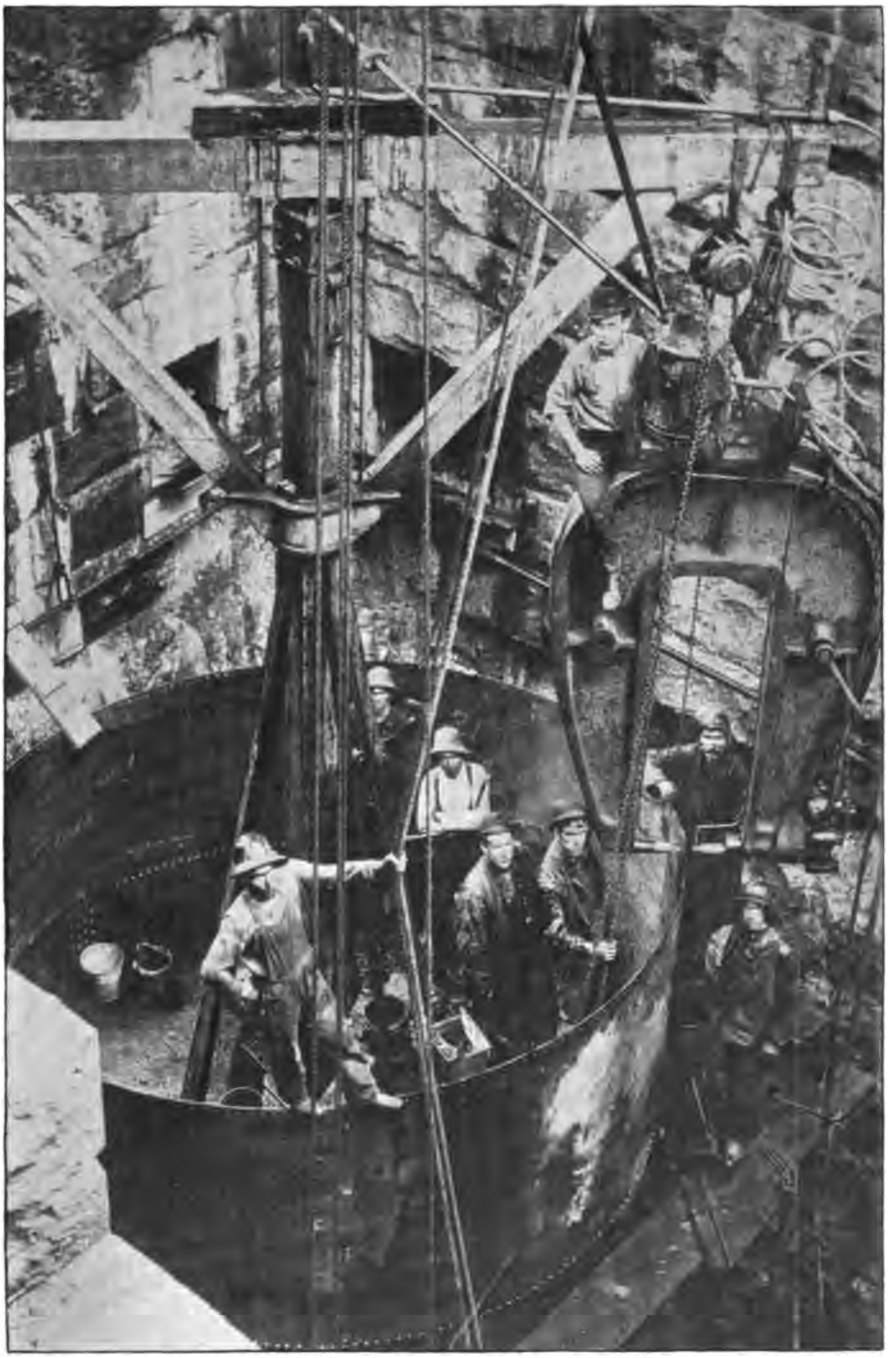


GENERAL ELEVATION OF FAESCH & PICCARD DESIGN.

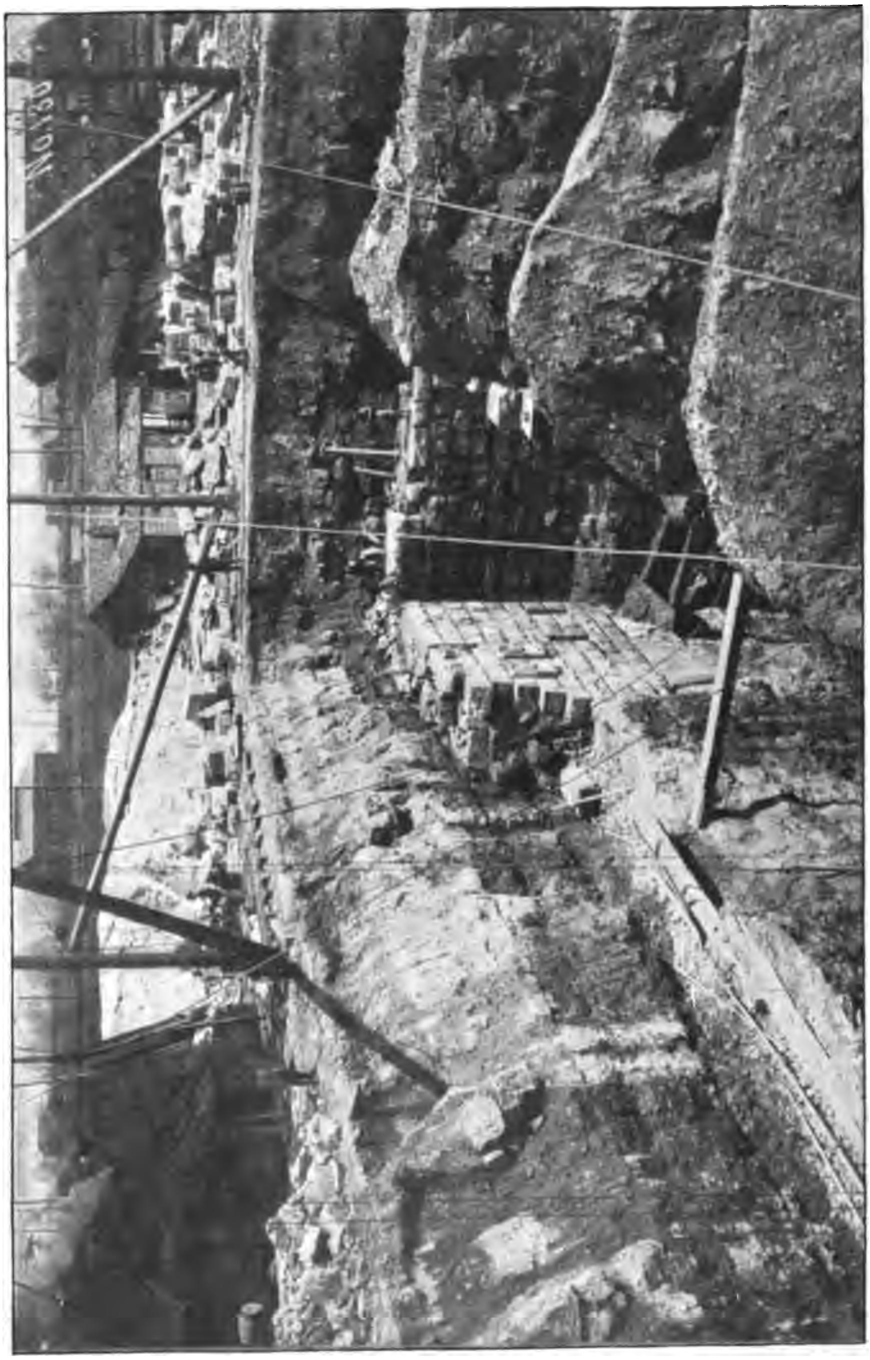


HALF SECTIONAL PLAN OF WHEEL DESIGNED BY FAESCH & PICCARD.

kept as small as possible at Niagara Falls, to economize rock excavation, as, for example, the branch tail-race just mentioned. Fall being a commodity of less than the usual value on these mill-sites, it is economy to spend some of it toward reducing cross sections. This produces high velocities, but the tail-races are built of first-class materials,



RIVETING UP THE PENSTOCK OF THE NIAGARA FALLS PAPER COMPANY'S PLANT.



A VIEW OF THE WHEEL-PIT DURING AN EARLY STAGE OF CONSTRUCTION.

and are set in a rock excavation. The water used carries no sand, and experience has already shown that the tailraces line themselves with a layer of slime in spite of the great velocity in them. So long as this slime adheres to the brick and to the cement joints, there can evidently be no wear of the brick masonry lining.

The wheel-pit of the Niagara Falls Power Company is a long slot cut in the rock, instead of a group of small wheel-pits, and to save excavation, though at the cost of some fall wasted, the wheels are set on plate-girder bridges spanning the slot, and so as to leave a tail-race beneath the plate girders. This tailrace, or bottom of the slot, is connected by a short curve with the main tail-race tunnel.

The fashionable turbine of the present day, in the United States, is, no doubt, the twin turbine, with horizontal axis, this axis projecting from the wheel case, at one or both ends, and either driving its attached machine directly, or carrying a pulley, to belt from. Several attempts were made to fit this general form of motive power for the case in hand. These all failed from the great space required for the belts or drive-ropes, which, in this case, would have had to be gained at the price of a material increase in the amount of rock excavation. Not to transmit the power to the surface of the ground and to attach the machinery underground, brings with it the necessity of excavated chambers 140 feet below

THE MOUTH OF THE TUNNEL.

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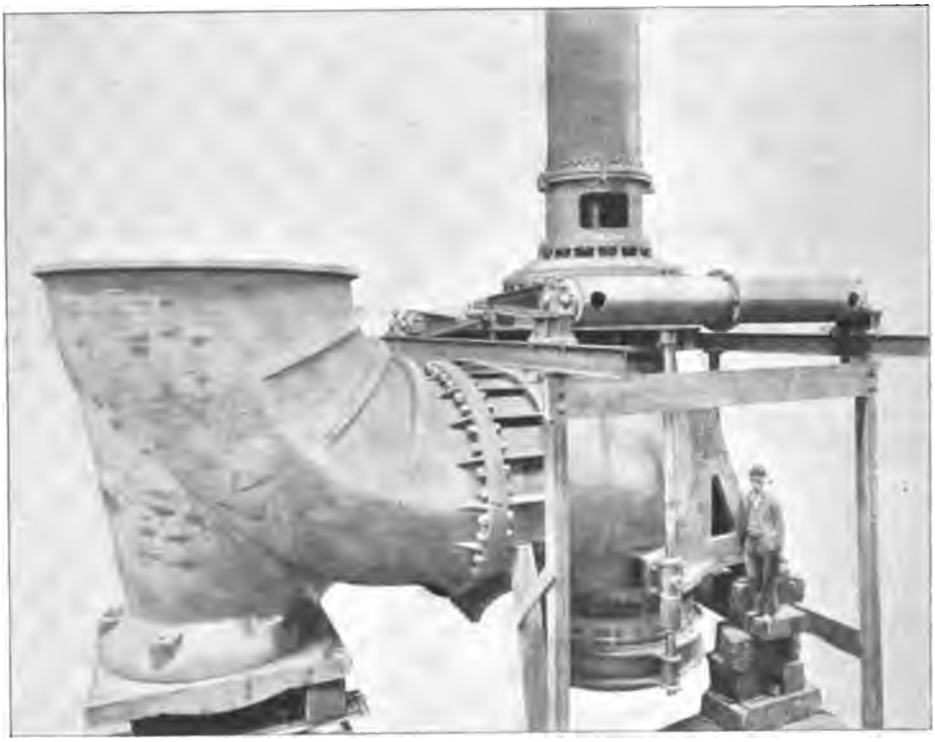


ONE OF THE NIAGARA POWER COMPANY'S 5000 HORSE-POWER TURBINES DESIGNED BY FAESCH & PICCARD, GENEVA, SWITZERLAND. BUILT BY THE I. P. MORRIS CO., PHILADELPHIA, PA., U. S. A

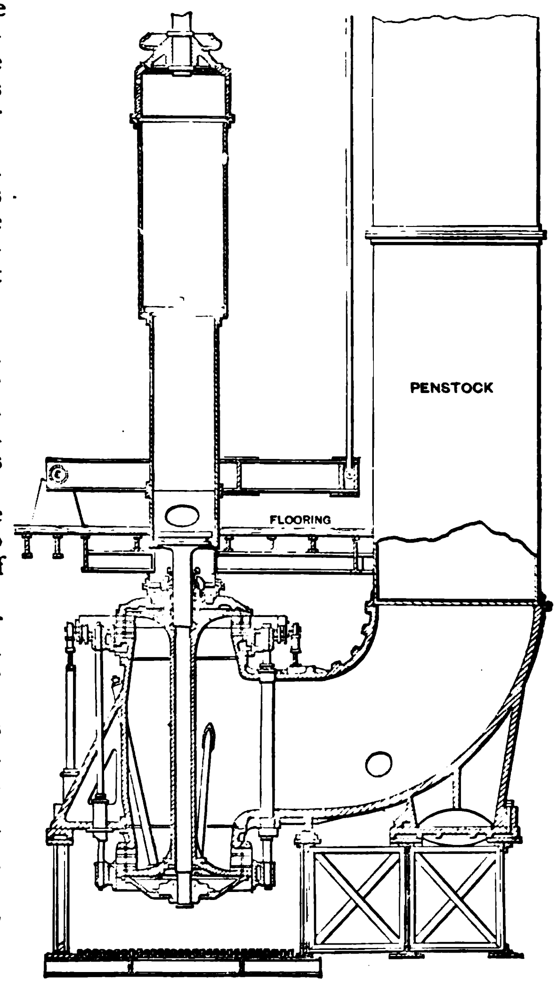
the surface, liable to be damp, or wet, and requiring constant artificial light; in short, forming a likewise undesirable arrangement. These considerations led, therefore, in the case of the Central Power Station of the Niagara Falls Power Company, to wheels with vertical shafts, and, as has been described, to rows of such wheels, set in a continuous slot, directly over the appurtenant tail-race; and to a group of such wheels, set in a square pit, for the Niagara Falls Paper Company.

Considerations of economy in regard to rock excavation per horse-power developed, led to large quantities of power per wheel; actually, to some 1100 horse-power per wheel in the case of the Paper Company, and to 5000 horse-power per wheel in the case of the Central Power Station. The very idea of a central power station serves, by the way, to meet considerations of economy in rock excavation, by avoiding the necessity of constructing wheel-pits to supply only small powers. When such small blocks of power are wanted, they will be furnished as parts of a larger plant, by transmitted power, as it would not pay to sink a wheel-pit for them alone. We may say, in round figures, that blocks of between 500 and 1000 horse-power will probably, and of less than 500 horse-power will certainly, be furnished on these mill-sites by transmitted power, and the Niagara Falls Power Company is preparing to transmit and distribute such power by electricity.

Given, then, turbines with vertical shafts of 5000 horse-power, on about 140 feet of fall, and a prescribed number of revolutions per minute, it follows that American wheel builders are not accustomed, or their shops not fitted, to supply such wheels. The turbine wheel business in the United States is, in point of fact, carried on in a way

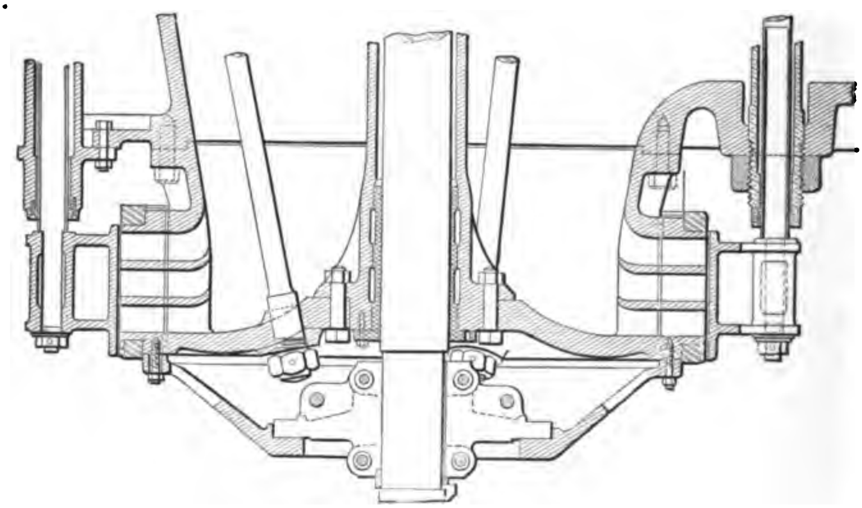
entirely different from the way the same business is carried on in Europe. While wheels built to order are the exception in this country, they are all but the invariable rule in Europe; and, while American builders have, ordinarily, stocks of wheels on hand and turn them out as they would shelf-hardware, wheels built in that way in Europe would there prove entirely unsalable. American wheels are mostly of a complex nature, as regards the action of the water on the buckets of the wheels, and have been perfected in efficiency by test, or, as it has irreverently been called, by the "cut and try" method of procedure. A wheel would be built on the inspiration of the inventor, then tested in a testing flume, changed in a certain part, and retested until no further change in that particular could effect an improvement; another part would then undergo the same process of reaching perfection, and thus, in course of time, the whole wheel would be brought up to the desired high standard of efficiency.

European wheels, on the other hand, are mostly of the standard simple action kinds, and have been perfected mainly by learned computations of forms of guides and buckets. Most American builders also shun high falls, and in their work, turned out in quantity, aim to suit only the ordinary heights of fall. The one special high fall wheel built in the United States, the Pelton wheel, has a horizontal axis. To use it on a vertical axis, and with the multiplicity of nozzles required for producing 5000 horse-power at Niagara, would constitute practically a new wheel. Swiss and other European wheel builders were, therefore, early in the field with designs for producing 5000 horse-power under a 140-foot fall, and having any desired number of revolutions per minute, which with their constant practice in building wheels to order, was, to them, only a case to be met, like most any other. The European designs all appreciated the difficulty of constructing a step, or bearings, that would sustain the great weight of a column of water 140 feet high, added to the weight of the shaft itself, and even of

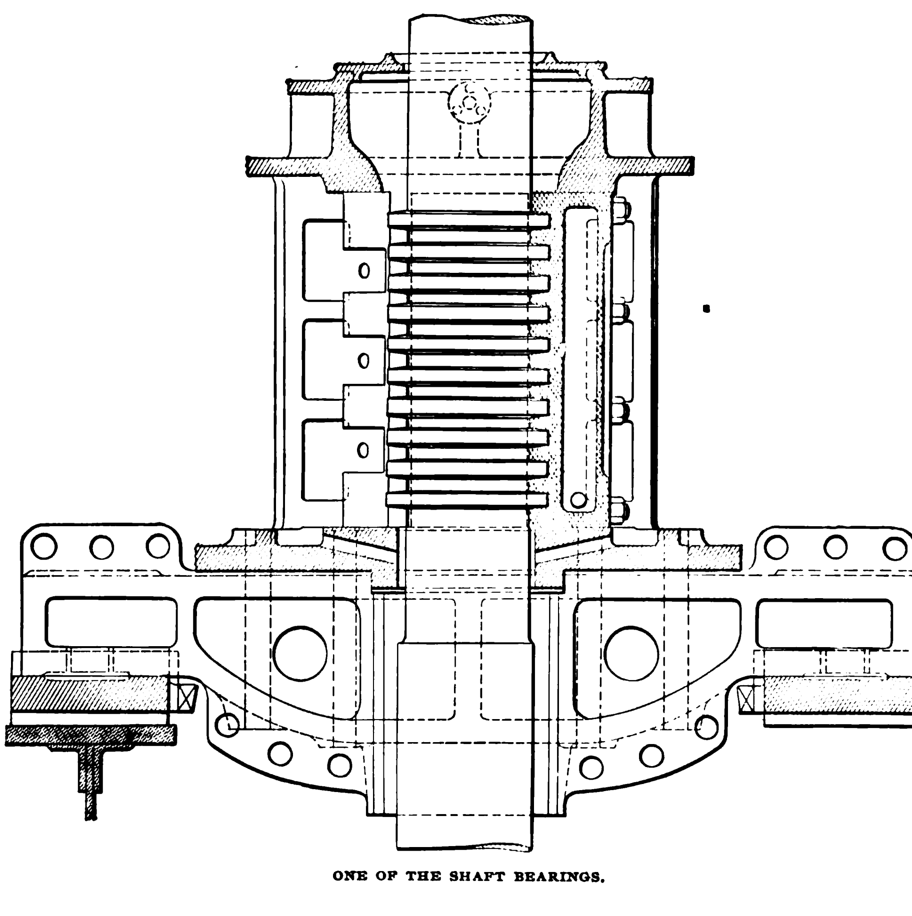


SECTION OF THE TURBINE.

the armature of a dynamo set on top of the shaft. To meet this requirement of construction some designed oil or water bearings along the line of the shafts; some designed hollow shafts, with an oil bearing on top of a column, ending near the top of the wheel,—the so-called Fontaine step; others de-



VERTICAL SECTION THROUGH LOWER WHEEL.

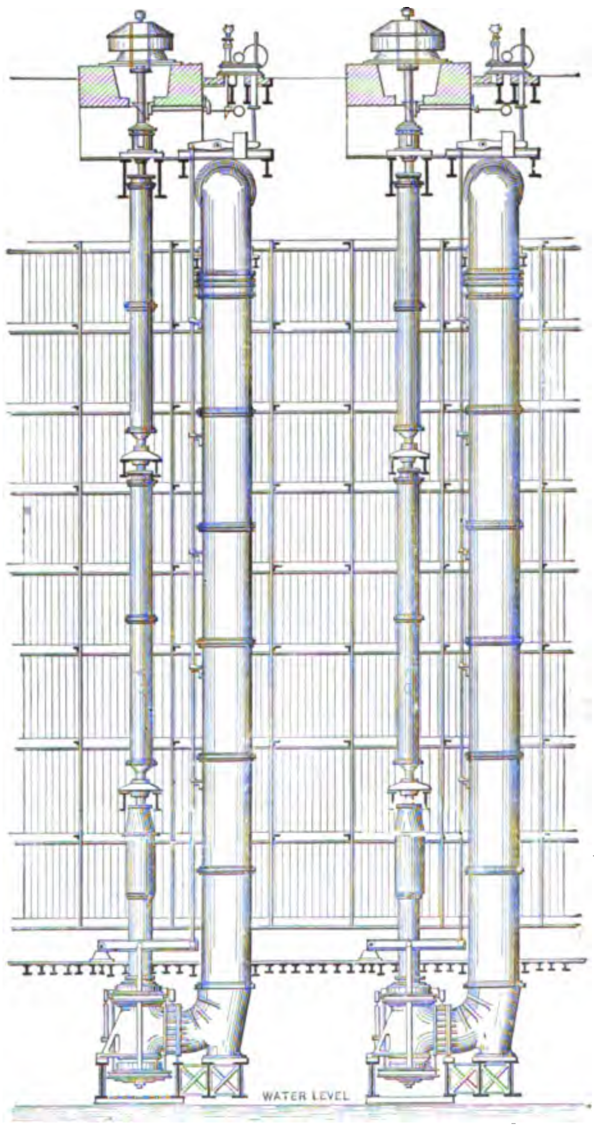


ONE OF THE SHAFT BEARINGS.

signed a water piston bearing; others hit upon the idea of having twin wheels set, the one larger in diameter and vertically over the other, and thus neutralizing the weight of the column of water acting on the wheels; and, finally, we have also a combination of certain of these methods of bearing, safely, the great weight on the revolving parts that support the wheel and the weights upon the shaft.

The wheels themselves, it is agreed among European turbine builders, must be either of the Fourneyron, in America often called Boyden, type, or else Jonval wheels. The 1100 horse-power turbines ordered by the Niagara Falls Paper Company are of the Jonval type, designed and built by R. D. Wood & Co., of Philadelphia, under the direction of the veteran Jonval wheel builder in the United States, Mr. E. Geyelin, and are very much like the Jonval wheels described below as submitted to the Niagara Falls Power Company by Escher, Wyss & Co., of Zurich,

ONE OF THE TURBINE CASTINGS.



GENERAL ELEVATION. FAESCH & PICCARD DESIGN.

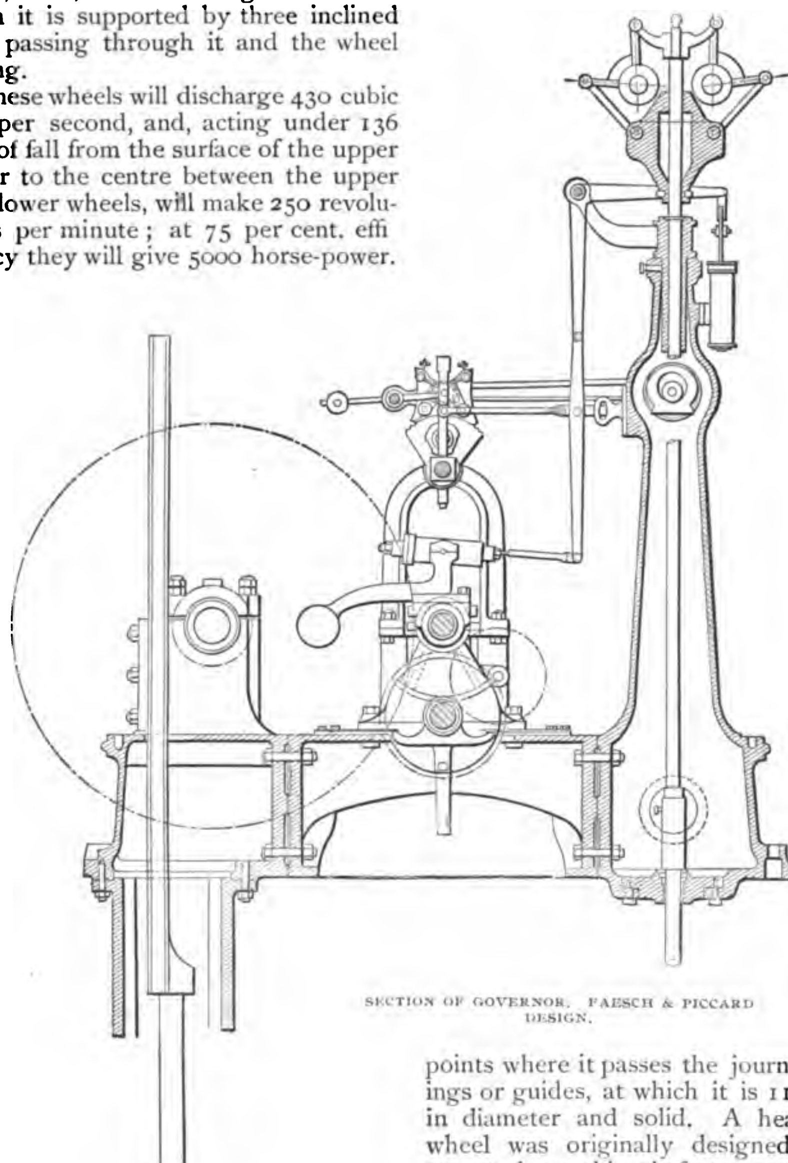
Switzerland, but omitting the upper of the twin wheels.

The three wheels now set and completed for the Niagara Falls Power Company were designed by Faesch & Piccard, of Geneva, Switzerland, and were built under contract with the I. P. Morris Company of Philadelphia. They consist of two Fourneyron turbines, one being set inverted and vertically over the other, so as to neutralize weight on the step or bearing. Each of these twin wheels is, moreover, made three stories high or deep, and the speed-gate consists of a cylindrical rim, moving up and down on the outside of each wheel. To further neutralize weight on the upper bearing of the shaft, the water from the penstock is allowed to pass through the disc of the

upper guide-wheels, and to act vertically upward upon the disc of the upper turbine wheel. The disc of the lower guide-wheel is, on the other hand, solid, and the weight of water upon it is supported by three inclined rods passing through it and the wheel casing.

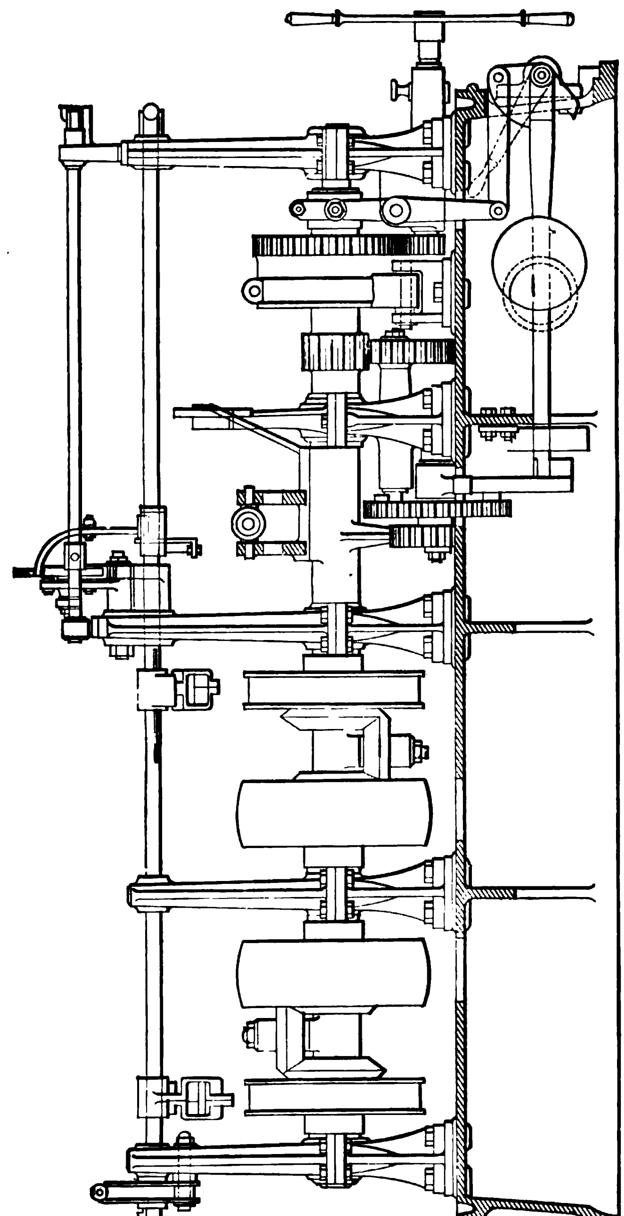
These wheels will discharge 430 cubic feet per second, and, acting under 136 feet of fall from the surface of the upper water to the centre between the upper and lower wheels, will make 250 revolutions per minute; at 75 per cent. efficiency they will give 5000 horse-power.

The guide-wheel has 36 buckets; the turbine-wheel, 32. These buckets are thickened in the middle, this being the most approved form of bucket, especially useful when the wheel is acting at part gate. The turbine wheels are made of bronze, the rim and buckets forming a single casting. The shaft is a steel tube, 38 inches in diameter, except at



SECTION OF GOVERNOR. FAESCH & PICCARD DESIGN.

points where it passes the journal bearings or guides, at which it is 11 inches in diameter and solid. A heavy fly-wheel was originally designed to be mounted on this shaft, to enable the governor the better to control the speed of the wheel, but has been replaced by the revolving field of the dynamo. This fly-wheel was to have been $14\frac{1}{2}$ feet in diameter, to have weighed 10 tons, and was to have been



SECTIONAL VIEW OF GOVERNOR, FAESCH & PICCARD DESIGN.

made of forged iron. It was designed for a circumferential speed of 11,400 feet per minute.

The speed-gates of the wheels are plain circular rims, which throttle the discharge on the outside of the wheels. This makes a balanced gate, easy of motion. Together with the governor shown and the fly-wheel, it is warranted by the makers to keep the speed constant within two per cent. under ordinary conditions of operation, and not to allow it to vary more than four per cent. should the work done be suddenly increased or diminished by 25 per cent. To shut the wheel down tight, reliance is had upon the headgates leading to the penstock. At the upper end of the main shaft is a thrust bearing, likewise shown in the drawings, to take up pressure along the shaft, in either direction — upward or downward. This pressure will, naturally, vary with the speed of the wheel, among other causes; hence a thrust bearing, thus operative in either vertical direction, is a necessity. A system of water cooling is provided for this upper thrust bearing.

PENSTOCK CONNECTION WITH TURBINE.

The plans of Escher, Wyss & Co. show twin Jonval wheels, but having their discharge from out of the wheel case in a horizontal direction; hence, capable of being governed, and actually governed, by a speed-gate of very much the same construction as that already described in the case of the Faesch & Piccard wheel. There is a post or column passing up through the wheel from the bottom of the wheel case, and an ordinary Fontaine oil-bearing near the upper limit of the case. These wheels, as drawn, are submerged, and they discharge sideways from the slot in which they are to be set, instead of having the tail-race formed at the bottom of the slot and directly under the row of wheels set on beams spanning the slot, as is the case for the turbines now erected. By placing the governor near the level of the water in the tail-race, water from the penstock is obtained under pressure, and the governor can be, and is, designed to be operated by hydraulic power.

In an article by the present writer, prepared several years ago, it was shown that Lowell, Lawrence and Holyoke, Mass., combined, had only one-fifth the horse-power now being developed by

the works of the Niagara Falls Power Company; that these cities had grown to have a population of about 150,000 people in 45 years, essentially by reason of having some 20,000 horse-power of water-power to keep their inhabitants in employment; that Niagara Falls is more favorably situated as regards freight rates to the rest of the United States than these cities are; and that it would, therefore, not be a rash prediction that the now existing (then future) city of Niagara Falls would have a million inhabitants in 50 years. This sentence, the ever active real estate boomer turned to his own uses, though to the discredit of its quoted author, by writing "in a few years," instead of 50 years. But such as it was then written, the author still subscribes to.

With a park on both sides of the river, that has restored and will forever preserve the natural beauties of Niagara Falls to succeeding generations; with a power development, likewise, on both sides of the river, that has been designed with full regard had to the preservation of all of these wonderful natural beauties; with constant power delivered at home and to the surrounding country, at rates never before offered so favorable; the future development of the Buffalo-Niagara Falls district, as a manufacturing centre, no less than as a place of residence, cannot fail to be one of the marvels of the fast approaching twentieth century.

THE FAESCH & PICCARD GOVERNOUR IN PLACE.

L. B. Stillwell

L. B. STILLWELL is the electrical engineer and assistant manager of the Westinghouse Electric and Manufacturing Company, and had under supervision the entire installation of electrical apparatus at Niagara Falls.

ELECTRIC POWER GENERATION AT NIAGARA.

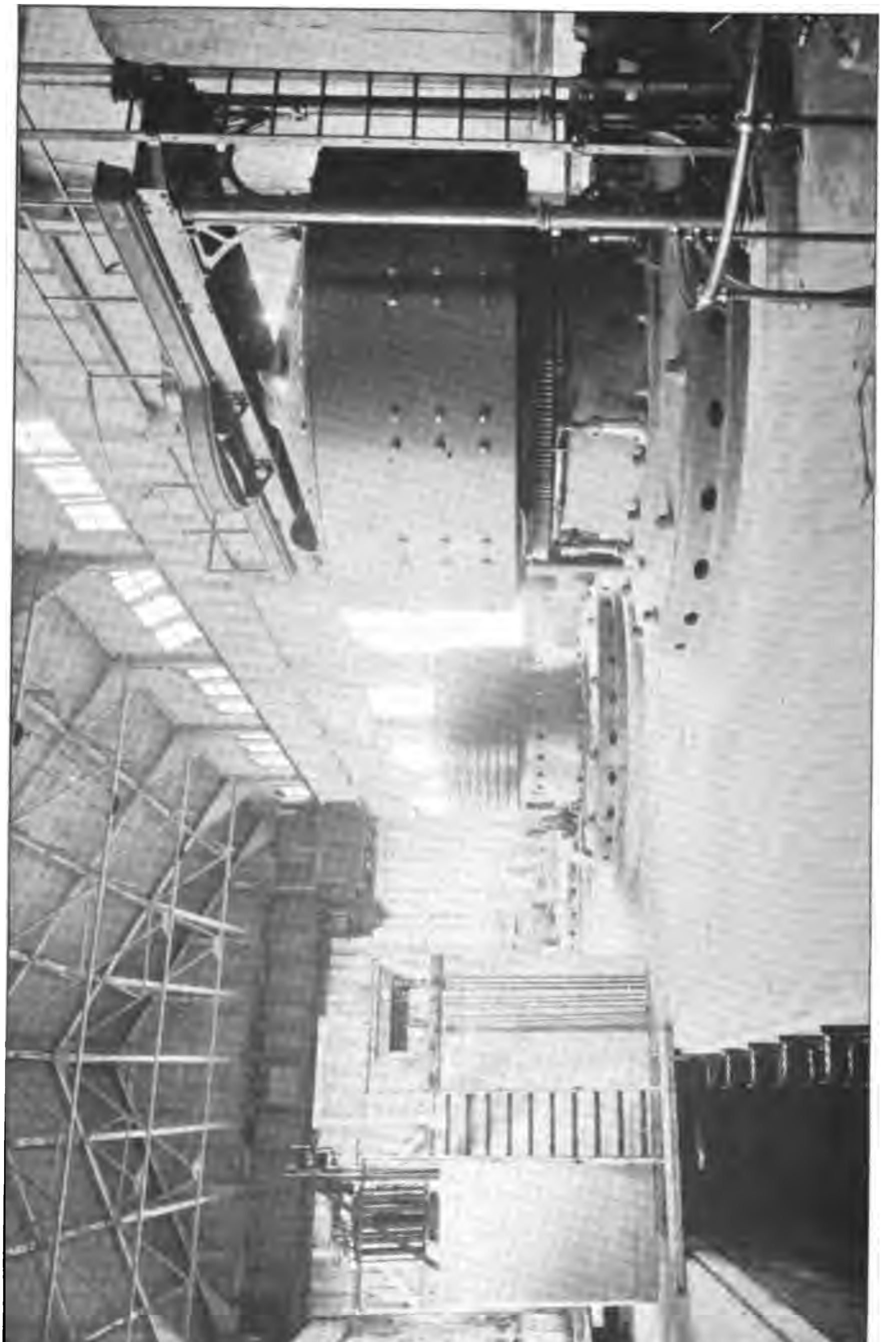
By Lewis Buckley Stillwell, Electrical Engineer.

ELECTRICITY as an agent for transmitting and distributing power has received its most weighty endorsement in its adoption by the Cataract Construction Company, of New York, for their great project at Niagara. No enterprise of modern times, involving special and extraordinary engineering problems, has been more carefully, more patiently, more systematically or more intelligently studied than has the utilization of this, the greatest water power in the world. The officers and directors of the company, controlling financial means ample for their purpose, have, for five years, energetically and persistently endeavored to avail themselves of the best resources of modern engineering science. Confronting a problem without precedent in its magnitude, and almost without parallel in its significance, they have attacked it with energy and ability of the highest order, studied it with keen insight and sound judgment and, in solving it with success, have contributed a chapter of rare interest and meaning to the history of industrial progress.

The utilization of Niagara for industrial purposes imposes upon those undertaking it a responsibility far beyond that which is measured by the capital invested. Science is cosmopolitan; she recognizes no boundary of race or nation; and engineering science of the twentieth century, in passing judgment upon the methods and apparatus employed, while not failing to take into consideration the difficulties and limitations imposed by the boundaries of our present knowledge, will allow no excuse for failure to find out and use the best means known to our age.

It is, therefore, a source of profound gratification that, from the outstart, the policy of the company has been characterized by a breadth of view commensurate with the far-reaching importance of the enterprise. The directors have allowed no local or even national prejudice to bias their judgment. They early threw the lists wide open and in the original competition which they inaugurated, the international commission passed upon no less than twenty-two plans covering practically the whole known range of electric, hydraulic and pneumatic distribution of power, and originating from places as far East as the city of Buda-Pesth, and as far West as San Francisco.

It must be gratifying to Americans that under these conditions a system developed by an American company has been adopted, but for the recent rapid advancement in engineering science which has made this work possible, America is in no position to claim exclusive credit, if she would. In the plans for the hydraulic plant, Switzerland, the land of water powers, shows the way, while in the design of the great electric generators, the most powerful as yet produced, Great Britain is represented directly in the excellent general form of construction adopted, which was proposed by Prof. Geo. Forbes, and indirectly in the work of Hopkinson, Kapp, Thompson, Mordey, and others, whose careful study of the principles underlying the construction of electrical machinery has done much to make it possible to design a machine so far beyond the range of actual experience, in full confidence that the results predicted from theory would



THE INTERIOR OF THE POWER HOUSE, SHOWING ONE GENERATOR COMPLETED.

be realized in practice. Perhaps no country is more largely or more creditably represented in the great Niagara installation than Smiljan Lika, —that sturdy little province on the Adriatic, which has honoured itself by producing Mr. Nicola Telsa, and were it possible to trace to its true source each one of the great number of ideas embodied in the complete installation, it is probable that we should find nearly every civilized nation represented—England, America, Switzerland, France, Germany, Italy, some in greater degree, some in less, but all co-operating to achieve what is, beyond question, one of the most significant triumphs of nineteenth century engineering skill.

The problem in electrical engineering presented by the Cataract Construction Company, as defined by the organization of the hydraulic plant in the power house and the requirements of the proposed market for the power developed, may be stated as follows:

Given, 1st:—Four vertical shafts, direct-driven by turbines making 250 revolutions per minute and capable of delivering at the top of each shaft from 5000 to 5500 mechanical horse-power. Additional turbines and shafts to be installed as the demand for power increases. 2d:—A market for power, beginning just outside the walls of the power house and extending at least twenty miles (and as much further as possible), said power to be used for, (A) general industrial purposes, such as the operation of machinery in mills and factories; (B) the operation of street railways; (C) lighting by arc and incandescent lights; (D) electrolytic purposes; (E) heating.

Required:—The most reliable and efficient method and machinery for utilizing the power for the purposes named.

The system or organization of electric apparatus which was adopted is known as the Tesla Polyphase Alternating-Current System. Each generator delivers alternating current to each of two circuits, the currents in these circuits differing from each other in their time relation, or phase, by 90 degrees; that is to say, the current delivered to each circuit attains its maximum value at the instant when the current delivered to the other circuit is zero. The frequency is 25 cycles per second,—in other words, the direction of the current is reversed 3000 times per minute. By means of rheostats, controlling the field circuits of the generators, the potential of the current delivered is adjustable up to the limit of 2400 effective volts. In ordinary service, and until transmission over great distances is undertaken, the normal potential will approximate 2100 volts, but, to compensate for the losses incident to long distance transmission, the generators may be operated at any potential not exceeding 2400 volts.

The currents delivered by the generators are conveyed through heavily insulated cables to the switchboard. There, by means of suitable switching devices, the engineer in charge of the station may, at will, connect any one of the generators, or any combination of the generators, to the external circuits which convey the currents from the power house to the consumers. These external circuits, known as feeder or supply circuits, passing from the switchboard, are supported upon iron brackets in a brick-lined subway within the power house, as shown in the illustration on page 286. Insulated, lead-covered cables are used, and these, leaving the subway, are continued through the bridge connecting the power house with the transformer house on the east bank of the power canal. The cables conveying current, intended for the use of tenants of the company and other consumers of power within a radius of 2 or 3 miles of the power house, pass directly through the transformer house and enter a conduit leading to the works of those tenants who are, at present, the principal users of the power.

Current intended for transmission to considerable distances, as, for example, to Buffalo, will pass from the switchboard through similar lead-covered cables in the power house subway and the bridge to the transformer house. There it will enter the "step-up" transformers, and from these current at high potential (E. G. 20,000 volts) will

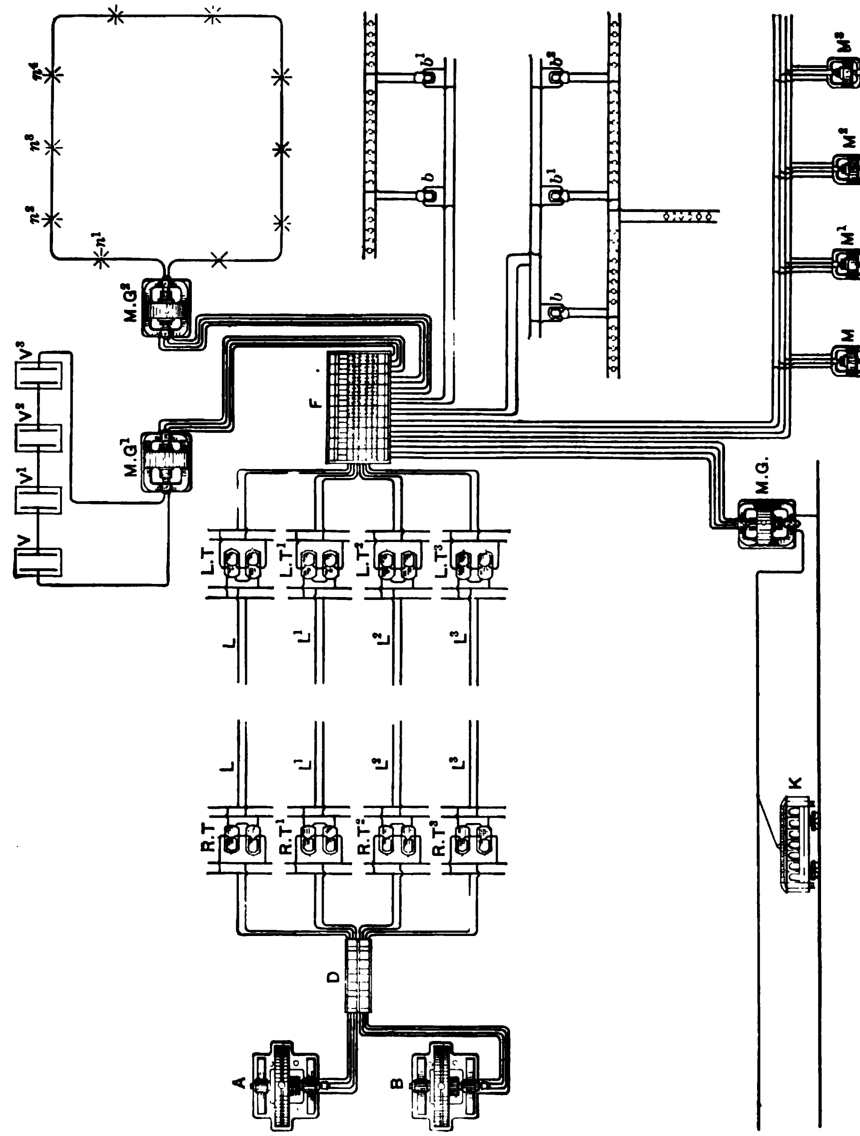


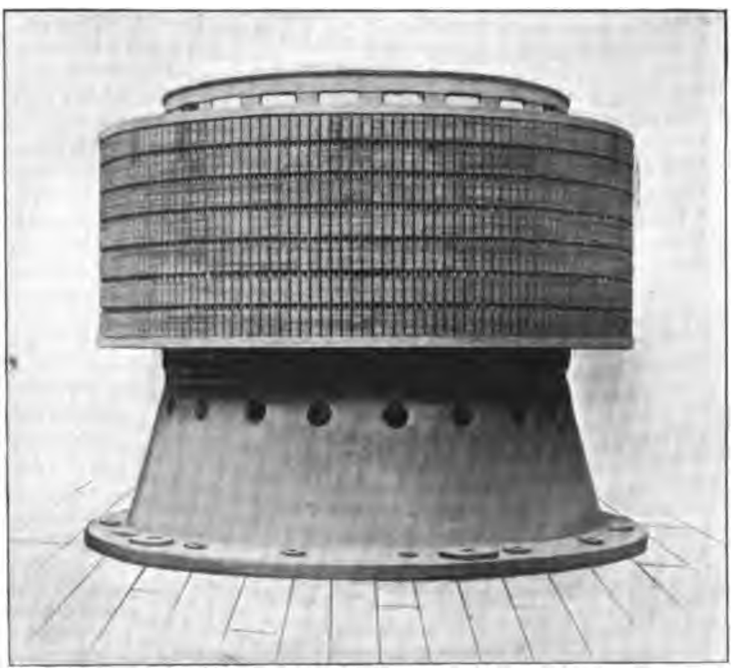
DIAGRAM OF A MULTI-PHASE SYSTEM OF ELECTRIC TRANSMISSION AND DISTRIBUTION.

be delivered to the long-distance transmitting circuits. It has not yet been determined whether these long-distance circuits shall be overhead or underground. At the distant end of the circuits "step-down" transformers will be employed to reduce the potential of the currents to an amount suitable for local distribution.

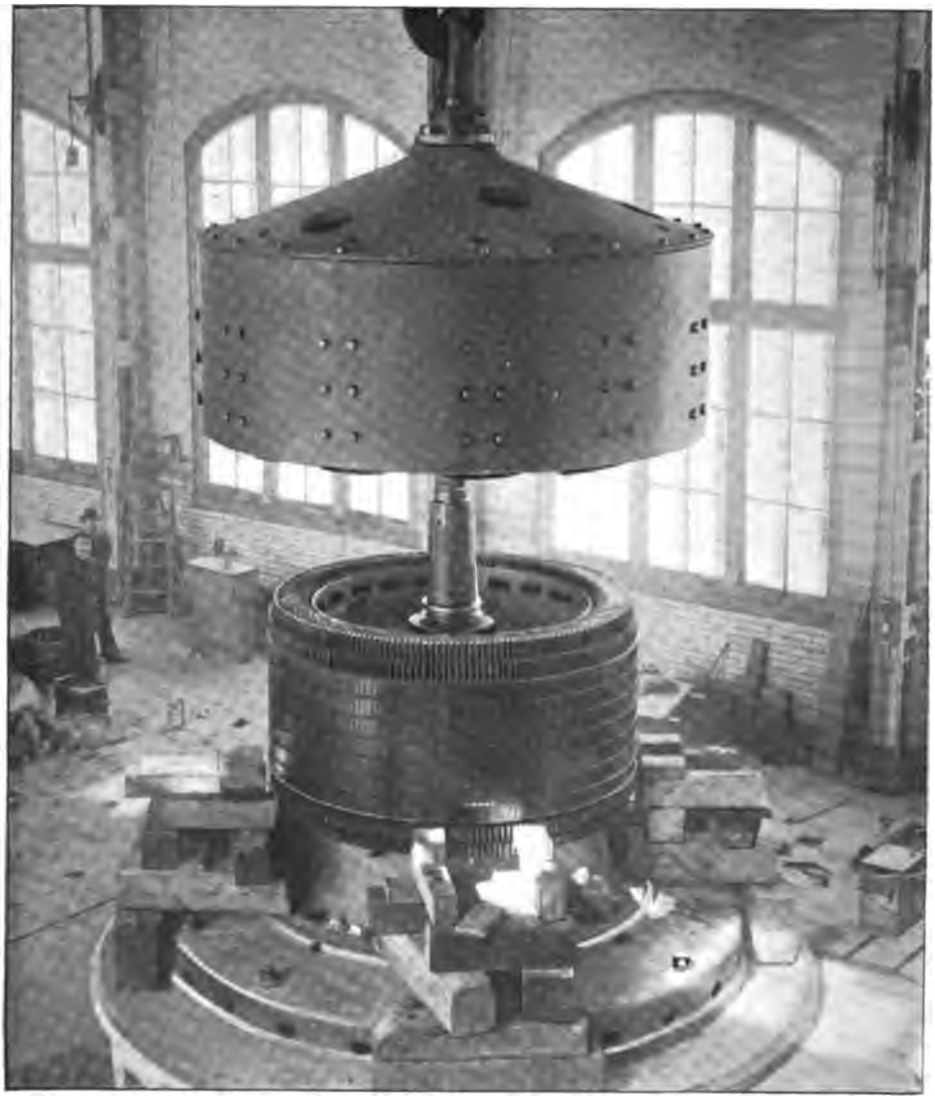
The kind and amount of apparatus which it will be necessary to install upon the premises of the users of power depends upon the kind of service required. In the case of large motors, the current delivered by the local distributing circuits at Niagara may be supplied to the machines without reduction of potential by transformers. In the case of smaller motors, and in the case of commutating machines used to supply direct current, step-down transformers will ordinarily be employed. The general organization of the system and character of the apparatus required for each of the principal types of service are illustrated in the diagram on the opposite page.

Referring to this diagram, each of the generators A and B delivers two separate and distinct alternating currents to the step-up or raising transformers RT, RT^1, RT^2, and RT^3, through the switchboard D. The current, delivered by the generators at 2000 volts, is transformed by the raising transformers to a high potential suitable to long-distance transmission, say 20,000 volts, and is delivered by them to the transmission circuits L, L^1, L^2 and L^3. At a point conveniently located with reference to the district where lights and motors are to be supplied a sub-station is erected. The transmission circuits enter the station and deliver their currents to the step-down or lowering transformers LT, LT^1, LT^2, and LT^3, which, in turn, deliver currents at moderate potentials, suitable for local distribution.

The switchboard F affords means whereby the circuits coming from the various groups of lowering transformers may be readily transferred and inter-



ONE OF THE 5000 HORSE-POWER ARMATURES.



A FIELD RING READY TO BE LOWERED ON A GENERATOR SHAFT.

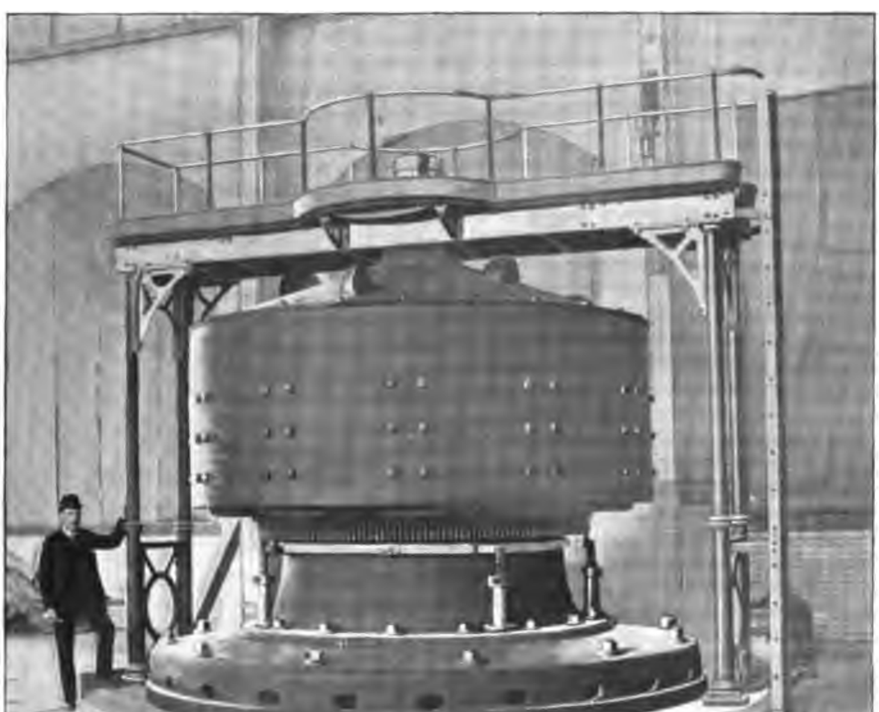
changed, so that any of the transmission circuits may be used to supply any of the local distributing circuits, as may be advantageous or convenient, or all of the local circuits may be supplied with current from bus bars to which the transmission circuits of like phase are connected in parallel.

In the diagram, beginning at the left of the switchboard, the first four-wire circuit is used to supply alternating current to the motor-generator or rotary transformer MG, which, in turn, delivers direct current at 500 volts to a trolley line, from which the street car K is supplied. The second circuit supplies the motors M, M^1, M^2, and M^3 of the two-phase, synchronous type, or of the induction type, which are adapted to general power purposes in mills, fac-

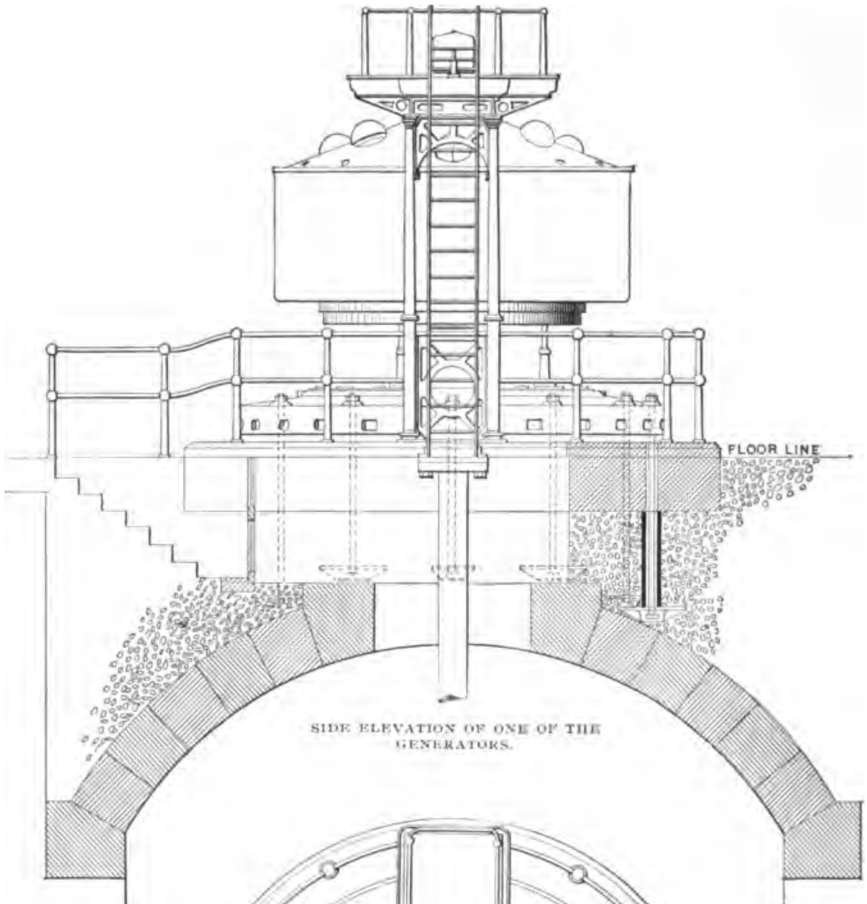
tories, etc. The next four-wire circuit is divided into two two-wire circuits, and is used to supply incandescent lamps through the transformers b, b^1, and b^2. The next circuit supplies alternating current to the motor-generator MG^2, which delivers direct current for arc lighting purposes. The last circuit shown supplies the motor-generator MG^1, which, in turn, delivers direct current at a low potential for electrolytic purposes, as indicated in the vats V, V^1, V^2, and V^3.

It is not intended to attempt the supply of incandescent lights in general in the manner indicated in the diagram, as the frequency is rather low for that purpose. At 25 cycles per second a slight wavering or variation in the intensity of the light is perceptible under certain conditions in the case of lamps having especially thin filaments, such as a 10 candle-power lamp for a 100-volt circuit. In 100-volt lamps of greater candle-power, and in 50-volt lamps, the light is entirely satisfactory. Arc lighting can, of course, be accomplished not only in the way shown in the diagram, but also by the indirect method of employing polyphase motors to drive arc light machines of the types generally in use.

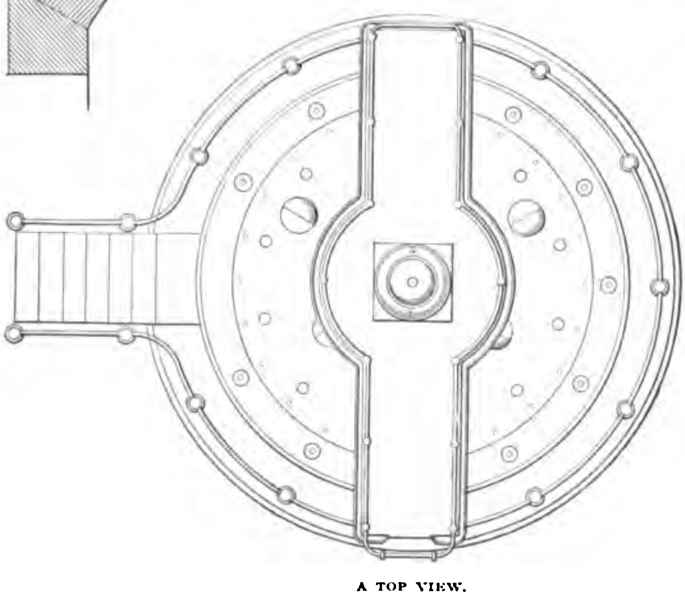
The frequency selected is in every respect admirable for power purposes, and was chosen in preference to a higher frequency because the amount of energy required for lighting from Niagara will, for many years, and perhaps for all time, constitute but a comparatively small part of the energy distributed. At present the only practicable way to utilize Niagara power for lighting purposes is by substituting motors for the engines now used in arc and incandescent lighting plants in Niagara, Tonawanda, Buffalo and other cities and towns to which the circuits may be extended. When the demand for



THE FIRST GENERATOR IN POSITION IN THE POWER HOUSE AT NIAGARA.



SIDE ELEVATION OF ONE OF THE GENERATORS.

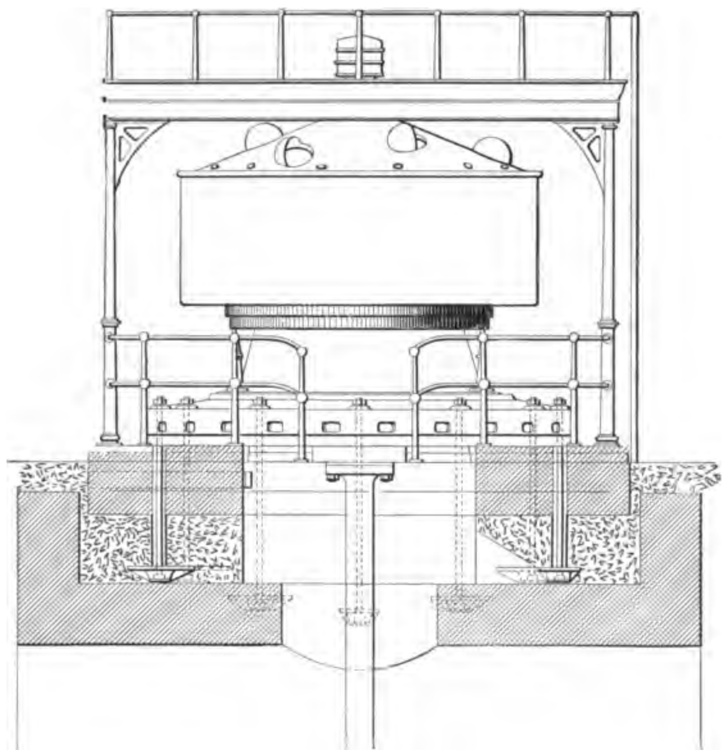


A TOP VIEW.

current to be used for lighting purposes becomes sufficiently important to justify a change in the apparatus, and, perhaps, in the methods now employed for lighting the cities and towns to which the circuits may be extended, a certain number of generators of higher frequency may be installed.

The drawings reproduced on this and the opposite pages are front and side elevations and a plan, showing the relation of the generator, the bed space occupied by the generators, with the actual size of the machine as shown on page 258.

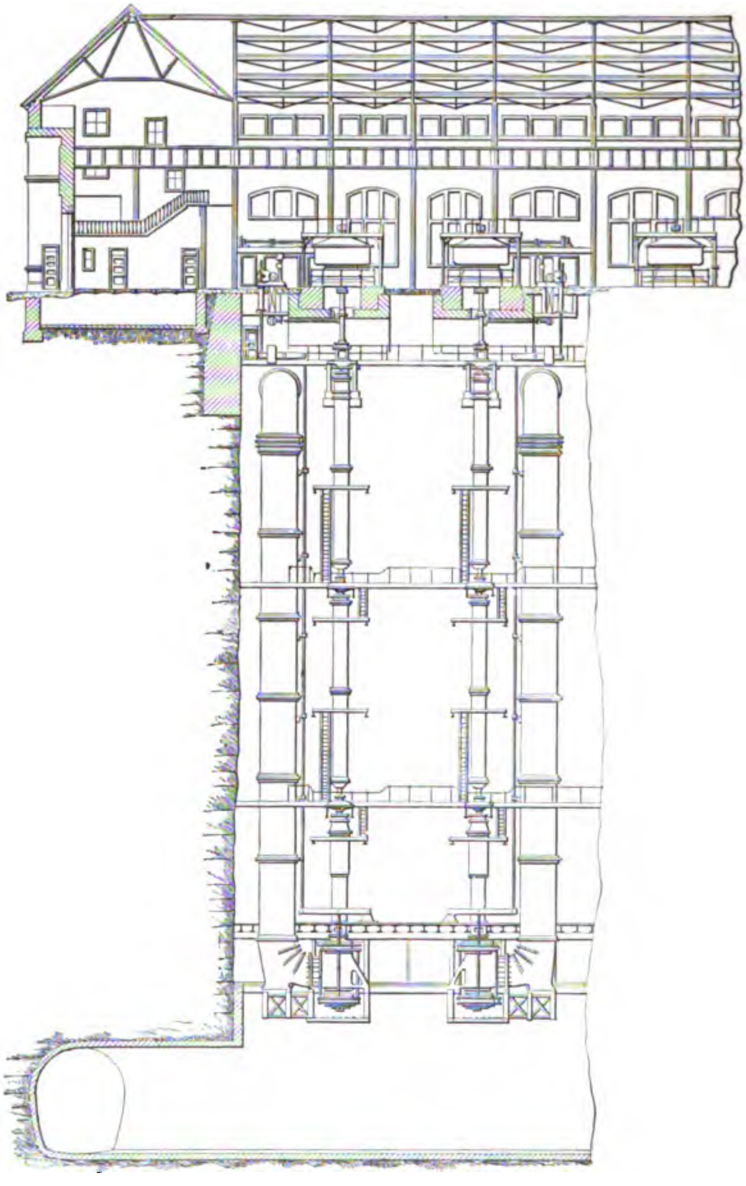
The height of each generator from the bottom of the bedplate to the top of the floor of the bridge is 11 ft. 6 in. The diameter of the bedplate is 14 ft., and the outside diameter of the revolving field ring is 11 ft. 7⅛ in. Each generator delivers 5000 electrical horsepower, and requires about 5150 horsepower delivered through the turbine



FRONT ELEVATION AND SECTION THROUGH FOUNDATION.

of concrete supporting the massive capstone and the excellently constructed arch which spans the wheel pit. On pages 262 and 263 sections through the power house and wheel pit, reproduced from the general drawings, show the generators in relation to the power house, the wheel pit and the hydraulic plant. The large scale upon which the work has been planned and carried out is graphically evident upon comparison of these sections, illustrating the relatively small shaft to drive it under full load. Exclusive of the bridge, which is simply used to give access to the brushes bearing upon the collecting rings at the top of the shaft, the entire machine could be placed in a room 15 ft. square and 15 ft. high.

The weight of each generator is 170,000 lbs., of which about 79,000 lbs. are in the revolving element, which is made up of the shaft, the driver to which the field ring is attached, the



PARTIAL LONGITUDINAL SECTION OF THE POWER HOUSE AND WHEELPIT.

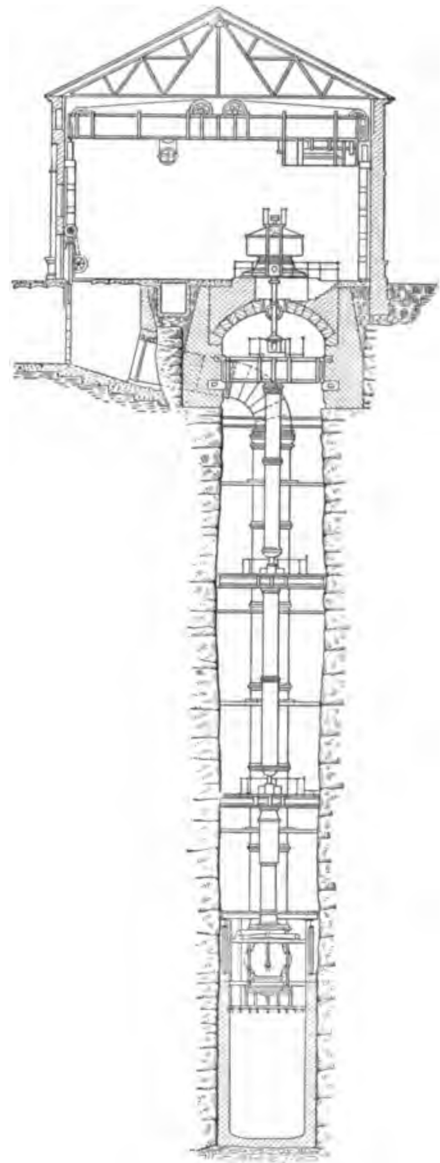
field ring with its pole pieces and bobbins, and the collecting rings, carried upon an extension of the shaft above the driver. The speed at which the field revolves is normally 250 revolutions per minute, and the fly-wheel effect of the revolving parts of the machine, measured by the pounds multiplied by feet per second squared, is 1,274,000,000.

The conditions to be met in the construction of the generators, as determined by the plans adopted for the hydraulic plant, were such as to impose very considerable difficulty upon the designers and manufacturers. These conditions were, in brief, an output of 5000 electrical horse-power, a speed of 250 revolutions per minute, a weight in

the revolving element of the machine not exceeding 80,000 lbs., and a fly wheel effect of the revolving parts, measured by the pounds multiplied by feet per second squared, of not less than 1,100,000,000.

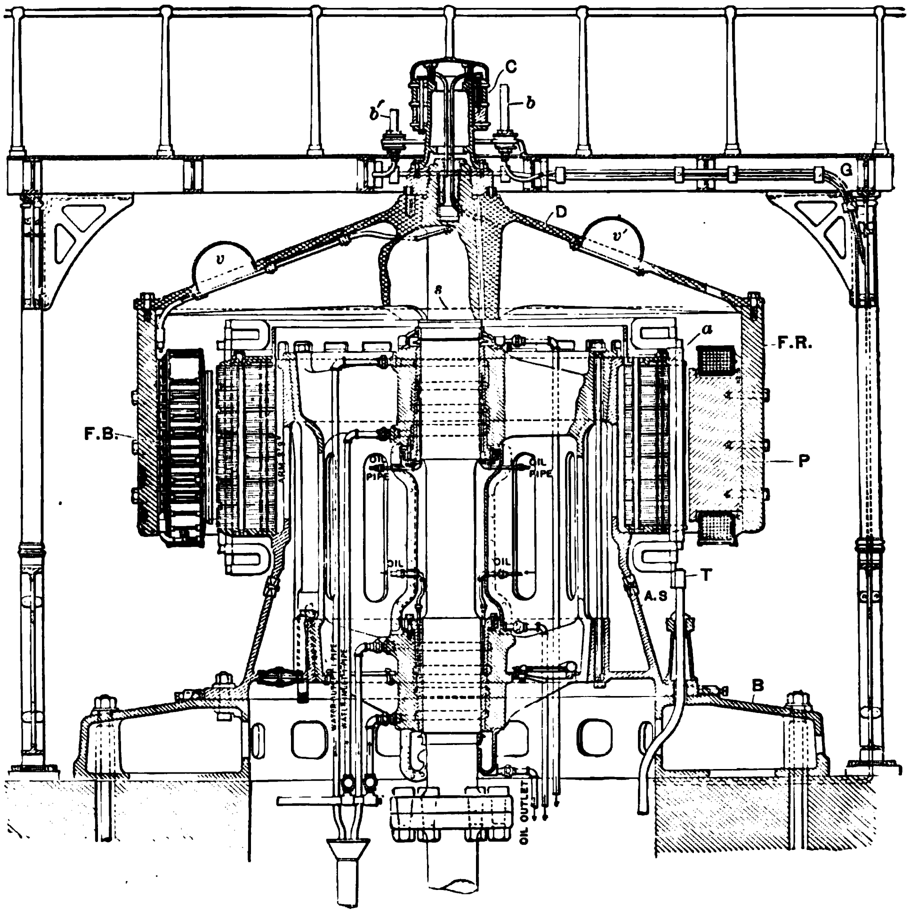
In saying that the imposition of these conditions involved difficulties, no reflection upon the wisdom of the decision which imposed these conditions is intended. It would be, perhaps, more exact to say that the general specifications laid down were such as called for the highest skill in the designers and builders of the generators. The conditions have been met successfully, and the object which the officers of the Cataract Construction Company had in view is attained. The Niagara generators represent to-day the highest state of the art of design and construction of electrical machinery.

The construction of the generators is illustrated by the reproductions from the general drawings on pages 264 and 265. In the vertical section through the centre line of the shaft on page 264, *a* represents the stationary armature, secured in place by the armature support AS, which, in turn, rests upon the bedplate B. One of the four terminals at which the current from the armature is delivered to the cables leading to the switchboard, is shown at T. Of course, since the armature is stationary, no ring collectors or brushes are needed. The revolving part of the generator consists of the shaft S, carrying the driver D, the field ring FR, the steel pole pieces P, the field bobbins FB (each bobbin surrounding a pole piece), and the collector C, by means of which the current delivered from the exciters to the brush holders *b*, *b′*, is conveyed to the field bobbins. In the horizontal section through the armature and field, *a* is the armature, FR the field ring, P, P′, etc., are the pole pieces and B, B′, etc., the field bobbins. The clearance between the armature and the field poles is one inch.



CROSS SECTION OF POWER HOUSE AND WHEELPIT.

The power house is equipped with a 50-ton electric crane, built by Messrs. Wm. Sellers & Co., of Philadelphia, which is of ample strength to handle any part of the electric or hydraulic machinery, and by means of this the revolving parts of the machines may be removed when necessary. In doing this the collecting rings near the top of the shaft are first removed, and the bridge is taken out of the way. The key which fixes the driver to the shaft is then withdrawn, and a special tool,



VERTICAL SECTION OF ONE OF THE 5000 HORSE-POWER GENERATORS.

which may be described as a combined eyebolt and hydraulic pump, is attached to the driver by eight heavy tap bolts. The pressure pump is then operated by hand, and, leakage of water being prevented by packing rings, a pressure of many thousand pounds, tending to lift the driver with reference to the shaft, is exerted. In this way the driver is loosened from the shaft, and, with the field, is then raised bodily by the electric crane. The bearings and the castings which support them are next lifted out, and the shaft is removed if necessary. When this has been accomplished, a clear space is left within the fixed part of the machine, that is, within the armature support, five feet in diameter, through which parts of the turbine shaft or other machinery from the wheel pit can be raised.

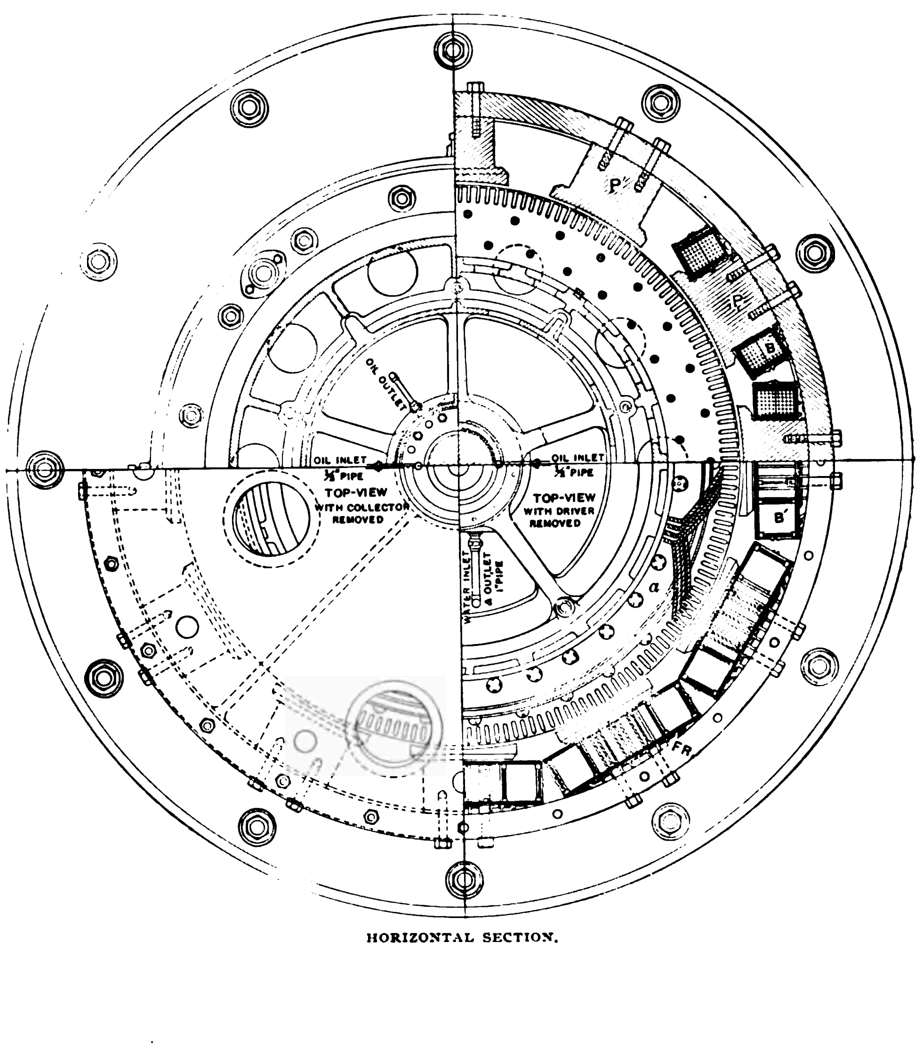
An attractive feature of the form of construction adopted is the fact that the magnetic attraction between the field poles and the armature acts against the centrifugal force. As compared with the centrifugal force at high speeds at which the ring must still be safe, the magnetic attraction is not very great, and, unless the field is charged, there is, of course, no magnetic pull between armature and field. But with normal conditions, this attraction tends to reduce the strains in the ring, due to centrifugal force, whereas, were the armature revolved inside of the field,

the magnetic pull would be added to the centrifugal force.

The armature and field are ventilated by means of openings in the driver, provided with special ventilators *v*, *v'*, so arranged as to draw air up through the machine, and throw it out at the top. A considerable draught is necessary, since, at full load, heat equivalent to about 100 horse-power, representing the loss in the generator due to magnetization of the iron and the resistance encountered by the currents traversing the conductors, must be dissipated.

The sections on pages 260 and 261 show the method of securing the bed plate in place. Eight 2½-inch bolts are used, and, at their lower ends, are securely held by castings buried in the concrete foundation. The masonry is of the highest class, massive blocks of Queenston limestone being used for the capstone and in the construction of the arch. In the latter a cylindrical steel casting takes the place of the keystone, the turbine shaft passing through it to the dynamo shaft above.

The armature support is a single casting of cylindrical form, and is securely bolted to the bedplate, upon which it is adjusted by set screws in a flange around the circular bed, and is afterwards babbitted to secure rigidity. This cylindrical casting has on its outer periphery a series of vertical ribs, which terminate at the lower ends in a flange upon which the armature ring rests. The latter was lowered to this flange



HORIZONTAL SECTION.

THE ARMATURE OF THE SECOND GENERATOR IN PLACE.

while heated, and then shrunk into place against the ribs on the cylindrical support. Five of these ribs are provided with dove-tailed keyways, corresponding with keyways in the armature ring. Into these, after the ring was shrunk into place, metal keys were cast. While the outer surface of this casting which supports the armature is cylindrical, its inner surfaces, at the top and bottom, form sections of two truncated cones into which fits and is securely bolted a second casting carrying two massive, five-arm spiders, which support the upper and lower bearings. The illustration on page 267 shows the armature support and armature core after the latter has been shrunk into place. The vertical slots which will be noted around the periphery of the core, are ready for the reception of the armature conductors.

The construction of the casting which carries the spiders supporting the bearings is illustrated on the same page. The end view shows the bushings in place, and these bushings are separately illustrated on page 268. The bearings, which are of the best quality of bearing metal, are in two parts, are fitted into conical bearings of iron surrounding the shaft, and are provided with set screws to assist in withdrawing or tightening when necessary. The bearings are lubricated by oil under pressure, admitted at a point midway between the top and bottom, and also at a point near the top.

Grooves are cast in the hub of each spider, with pipes at each end, permitting the circulation of water to cool the bearings, this water being conveyed to the bearings direct from the city mains at a pressure of 60 pounds per square inch. The oil is supplied from a reservoir placed at an elevation of about 30

ft. above the upper bearing. After having passed through the bearings, it is filtered and pumped back into the reservoir. The pressure at which it is supplied to the machine is that due to gravity.

THE ARMATURE SUPPORT AND CORE.

The illustrations on pages 269 and 266 show, respectively, the armature core, or ring, in place upon its support before winding, and the armature complete, with conductors in the grooves or slots around the periphery of the core. The armature core is built up of

SIDE VIEW OF CASTING CARRYING SPIDER FOR BEARINGS.

thin sheets of mild steel, No. 30 B. W., G., and, to secure free circulation of air, is divided horizontally into six equal parts, separated from one another by one-inch spaces. Each layer of the core consists of eleven segments, which are so placed that all joints in each layer are overlapped by the segments of the adjacent layers. One of the sheets of steel is shown on page 268. These pieces are punched out of large sheets of a certain predetermined quality, .015 of an inch thick, by steel dies in powerful presses. They are afterwards thoroughly annealed. In this process of annealing, the surfaces of the segments are oxidized, the oxide serving as insulation to reduce the eddy currents which are set up in the iron of the armature when the machine is in operation.

The ring thus built up is securely held together by sixty-six bolts of nickel steel, containing a high percentage of nickel which renders them practically non-magnetic. These bolts are, of course, carefully insulated from the core. The large discs, or end-plates, at the top and bottom of the armature ring are of brass. At the time of tightening the bolts, the steel plates are pressed closely together by

END VIEW OF THE CASTING.

powerful hand-presses. The six equal parts, or layers, into which the core of the armature is divided, are separated from one another by segments of cast brass, these segments being cast in such form that, while they have sufficient strength to withstand the pressure under which the armature core is assembled, the larger part of the spaces between the six adjacent rings or steel plates is left open for the circulation of air.

The armature ring, when finally

built up, is turned on the inner surface so as to accurately fit the ribs of the armature support. It is then heated, and lowered into place against the flange on the support, and, in cooling, shrinks itself tightly into place against the ribs.

The armature conductors consist of copper bars $1\frac{11}{16}$ in. by $\frac{7}{16}$ in. in section, the edges of the bars being rounded to a radius of about one-eighth of an inch to avoid cutting the insulation. Two of these bars, after being insulated, are placed in each of the 187 slots around the periphery of the armature core. The conductivity of the bars used is above 100 per cent., by

DETAILS OF ARMATURE BEARINGS.

Matthiesen's standard. In the case of the second generator the conductivity of the copper, furnished by the Washburn & Moen Mfg. Co., of Worcester, Mass., is 102.6 per cent., which strikingly illustrates the fact that what was considered pure copper when the standard referred to, and still generally used,

ONE OF THE SHEETS MAKING UP THE ARMATURE CORE.

was determined, is now inferior to certain grades of commercial copper. The proper insulation of these conductors is a matter of the greatest importance. Each conductor must be separated from its neighbors and from the iron of the armature core by insulating material which is abundantly able to withstand the potential to which it will be subjected, and in order to be sure of this, a large factor of safety is allowed; that is, the insulation is tested by apply-

JUNCTION OF ARMATURE BARS AND CONNECTORS BEFORE SOLDERING AND INSULATING.

ing a potential several times as great as any to which it will be subjected in service.

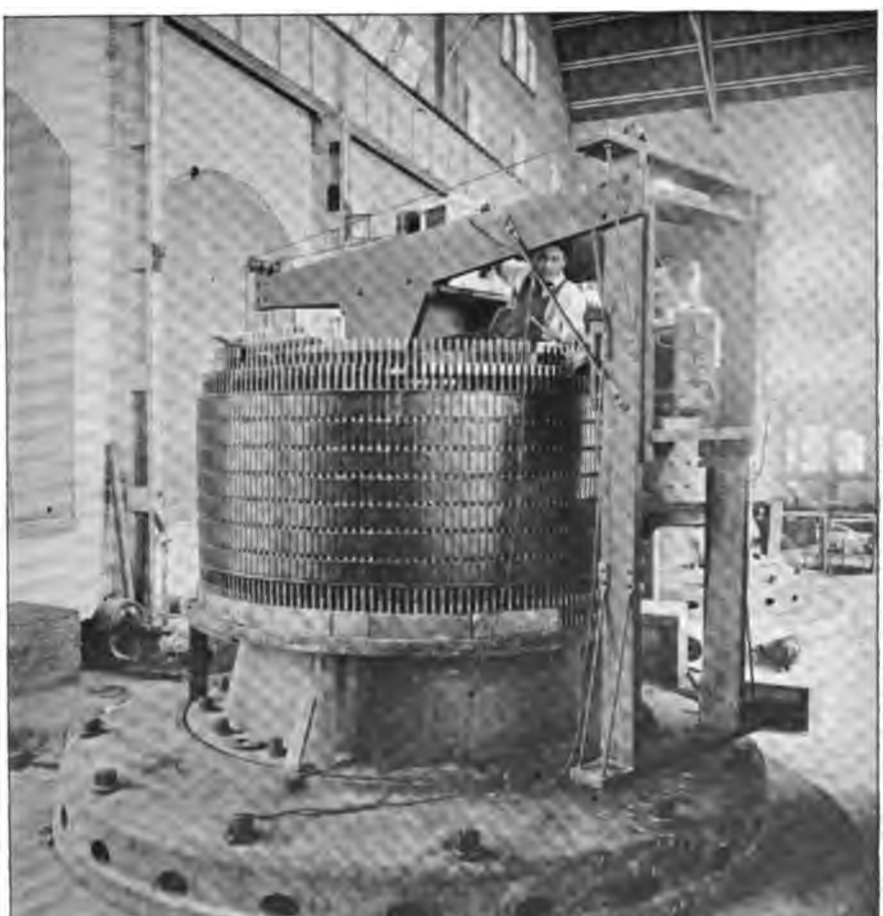
At the factory, the insulation of each bar was tested by applying a potential of 15,000 volts. One terminal of the transformer used in testing was connected to the conductor, and the other terminal was connected to a layer of tinfoil, wrapped about the outside of the insulation. During the erection of the generators at Niagara, the insulation was again tested by applying a potential of 6000 volts, one terminal of the testing transformer being connected to the conductors, while the other was connected to the armature core. An alternating potential was used in both tests, and the values given are in each case the mean or effective potential.

The material used for insulating the bars is principally mica. The armature conductors project above and below the core, as shown in the illustration on page 269, and connections are made by pieces of copper, punched from large sheets and shaped into proper form by presses and iron moulds. These connectors are insulated by mica and rubber insulating tape, the former being used only where connectors conveying

currents of considerable difference of potential are adjacent to each other.

It is very important that good electrical connection be made at the junction of connector and armature bar. The illustration on page 268 illustrates the connection before the solder is applied. Three holes drilled through the split end of the connector correspond to three holes in the end of the armature bar. The split end of the connector is fitted closely to the end of the bar, and when the holes in the connector and bar are properly aligned they are securely fixed in place by three wrought iron bolts, the holes through one side of the connector being reamed out to receive the heads of the bolts. After the nuts are tightened into place, the projecting ends of the bolts are upset; that is to say, they are split and, as it were, riveted to lock the nuts.

The joint is then thoroughly soldered, this work being greatly facilitated by the use of an electrical soldering tool. The process will be best understood by referring to the illustration on this page, which was taken during the erection of the first generator. A transformer, supplied with alternating current at a potential of about 150 volts, is so wound as to deliver a current of very large quantity but low pressure. This current is coveyed through heavy jaws, or terminals, of copper to the point of junction between the armature bar and



ELECTRICALLY SOLDERING THE CONNECTIONS OF AN ARMATURE WINDING.

its connector, and in a few seconds this point is heated to a high temperature. The joint is then readily flooded with solder. This is afterwards dressed up by a file, and the joint is thoroughly insulated.

In the illustration the soldering transformer and one of the operatives are seen carried at one end of an oak frame, supported upon the shaft of the generator and counter-weighted at its opposite end. In soldering the connections the operative slowly revolves the frame about the armature. The seat which carries him is adjustable, so that the connections at the bottom of the armature, as well as at the top, can be reached, and it is provided with rails upon which the transformer is pushed forward until the copper jaws grasp the connection, or withdrawn after the soldering is completed.

When the armature is completely wound, as shown in the illustration on page 266, the conductors are so connected as to form two complete circuits, each thoroughly insulated from the other and from the steel core, and so related to each other that the electromotive forces induced in them by the revolving magnetic field are ninety degrees apart.

THE GENERATOR SHAFT.

Coming now to the revolving parts of the generator, we begin with the shaft, which is shown on this page. It is of open-hearth steel, and was forged and rough-turned by the Cleveland City Forge and Iron Company of Cleveland, Ohio. The diameter of the shaft in the bearings is $12\frac{15}{16}$ in. It is tapered at the upper end to receive the driver, and a flange, 27 in. in diameter, is forged at the lower end to provide means for connection to the flange at the top of the turbine shaft. These flanges are bolted together by eight tapered steel bolts. At its extreme upper end the shaft is threaded to provide means for securing

THE DRIVER FOR THE FIELD RING.

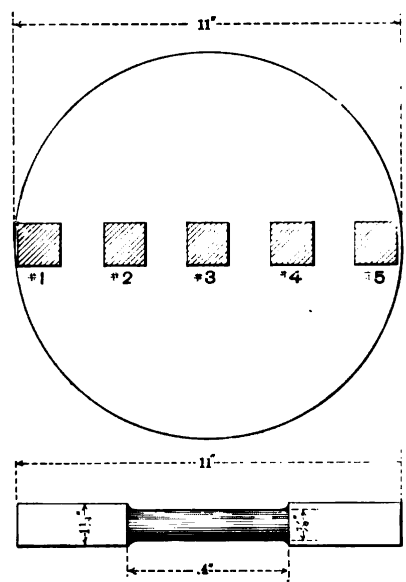
in place the revolving parts which project above the driver and carry the collecting rings.

For the purpose of securing information as to the physical properties of the steel used for the shaft, it was originally forged of extra length ; an end, several inches in length, was then cut off, and from this five samples were taken, two being cut from the periphery of the shaft at opposite ends of a diameter; one, from the centre of the shaft; and two, from points midway between the periphery and the centre, as illustrated in the cut on this page, where the numbers 1, 2, 3, 4 and 5 indicate the places in the section of the shaft from which the test samples were taken. These samples were tested by the Pittsburgh Testing Laboratory at Pittsburgh, and the fact that forged shafts are stronger near their outer surface than elsewhere is shown in an interesting manner by the results, which are set forth in the following table :

Sample No.	Tensile Strength in Pounds Per sq. in.	Elastic Limit in Pounds Per sq. in.	Reduction of Area in Percentage of Area Before Test.	Elongation in Percentage of Length Before Test.
1	63,000	35,500	53	37.5
2	59,000	29,500	51	38
3	56,000	28,500	37 5	31
4	58,500	31,500	41.5	38
5	62,500	35,000	55.5	35

A view of the driver is given on page 270. It is 11 ft. 8 in. in diameter. As has been noted in describing the shaft, the latter is tapered at its upper end, and by referring to the illustration on page 270 it will be seen that a heavy key-way is cut into the tapered portion. The bearing in the driver which fits over this tapered end of the shaft is also provided with a key-way, and the driver and shaft are held together by a long and massive steel key. The driver is of mild cast steel, and was turned out by the Midvale Steel Company, of Philadelphia. It was guaranteed to have a tensile strength of about 60,000 lbs. per sq. in., but the tests of samples of steel, taken from the casting near the periphery of the first driver, showed a tensile strength of 74,700 lbs. per sq. in., an elastic limit of 44,590 lbs. per sq. in., an elongation of 30 per cent. in 3 in., and a reduction of area of 43 per cent. The surface of the fracture was silky and fine-grained. The drivers are turned on their outside surfaces and are strengthened by six deep ribs on the inside.

Perhaps the most interesting part of each generator is the field magnet ring, which not only illustrates the wonderful physical properties of nickel steel, but demonstrates in a most striking manner the perfection of modern forging ma-



TEST PIECES FROM THE GENERATOR SHAFT.

chinery and the skill of those who use it in the great plant of the Bethlehem Iron Company, at South Bethiehem, Pa. The ring is forged in one piece without weld, and is shown in the photographic reproduction on the following page. The Bethlehem Iron Company guaranteed that the rings for the first three generators should have a tensile strength of not less than 70,000 lbs. per sq. in., an elastic limit of 38,000 lbs. per sq. in., and an elongation of about 25 per cent. in 2 in.; but they have done much better. Three samples, cut from the first ring before

NICKEL STEEL FIELD RING, FORGED WITHOUT A WELD BY THE BETHLEHEM IRON COMPANY. DIAMETER, 11 FT. 7⅛ IN.

turning were tested with the following results :

Sample No.	Tensile Strength Measured in Pounds Per sq. in.	Elastic Limit Measured in Pounds Per sq. in.	Elongation in 2" Measured in Percentage of Original Length.
1	82,915	53,560	27.05
2	81,110	47,230	25.75
3	82,140	49,280	22.5

The following brief account of the method of making the field rings is based upon notes furnished by Mr. R. W. Davenport, second vice-president of the Bethlehem Iron Company. A nickel steel ingot, 54 inches in diameter at the bottom, 197 inches long, and weighing about 120,000 lbs., was cast solid, and compressed by hydraulic pressure when fluid and during solidification. This ingot is shown in the illustration on page 274. A hole was bored through its longitudinal axis, as shown on page 275, and a block of proper weight was then cut from the ingot. The cylinder thus formed was brought

to a forging heat, and expanded on a mandril under a 14,000 ton hydraulic press. The high degree of skill, and the perfection of mechanical appliances required to expand part of the cylinder, shown on page 275, to the ring, illustrated on page 272, are evident, and reflect much credit upon the Bethlehem Iron Company. After forging, the ring was carefully treated to obtain the physical qualities desired, and was then bored and rough-turned on a large boring mill. It was finally turned true in the shops of the Westinghouse Electric & Manufacturing Company, at Pittsburg, Pa.

Not only are the physical properties of the ring extraordinary; in size it is without precedent, and to those interested in the recent remarkable improvement in the quality of steel, and in the methods of working it, the interest which attaches to this ring, as an example of the finished product of the Bethlehem Iron Company, is not less than that which it derives from the important part which it sustains in the Niagara installation.

Why it is necessary that these rings should be so strong, and that they should be so forged as to eliminate the possibility of weakness in any part, will be better understood when we consider the speed at which they revolve, and the weight of the pole pieces and field bobbins which they carry. The illustrations on page 276 show one of the field poles without its winding, and one of the field poles with bobbin in place. The poles are of mild open-hearth steel, and were cast by the Midvale Steel Company. Their magnetic qualities have been carefully tested by sample, and are excellent.

The field winding, which consists of copper conductor of rectangular section, thoroughly insulated, is contained in ribbed brass boxes or covers, one of which is well illustrated on page 276. The weight of each pole piece with its bobbin is 2800 lbs. The relation of the pole pieces and bobbins to the ring is shown in the illustration on page 277. The speed of the ring at its periphery is 9300 ft. per minute when making 250 revolutions per minute, and at this speed the centrifugal force, due to each field pole and bobbin, is 2727 lbs. The strain is, of course, a maximum at a point in the ring midway between each pair of adjacent poles. The strain due to the mass of the ring itself is 2325 lbs. The total maximum strain in the ring at 250 revolutions per minute is, therefore, by calculation, 5052 lbs.

It is not sufficient that the ring should be simply strong enough to withstand the centrifugal force due to the field poles, bobbins and its own mass when revolving at 250 revolutions per minute; it must be able to run safely at a much higher speed, for it is conceivable that, should anything happen to the apparatus which governs the turbines, a much higher speed may be attained. It was judged necessary, therefore, to so design the machine that it should be safe when running at a speed of 400 revolutions per minute, and at this speed the centrifugal force due to each pole piece and bobbin becomes 6500 lbs. The strains in the ring have been, as may be supposed, calculated with great care, and even at 400 revolutions per minute, equivalent to 241 feet per second at the periphery, the total strain will not exceed 13,000 lbs. per sq. in. As the elastic limit of the material used in the rings is 48,000 pounds, the factor of safety at this speed, which will probably never be realised in practice, is nearly four. At a speed of 800 revolutions per minute, which means 482 feet per second, or nearly six miles per minute at the periphery, the ring would burst. But it is, of course, impossible that any such speed could, under any circumstances, be attained; in fact, the calculations of the designers of the hydraulic machinery show that the speed could in no case exceed 400 revolutions per minute.

Above the driver in the illustration on page 254 are the collector and brushes by which the current is conveyed from the exciters to the revolving field of the generator. The conductor conveying the field current comes from the exciters through covered conduits beneath the level of the floor, passes

SOLID INGOT OF FLUID COMPRESSED STEEL USED FOR MAKING THE FORGED FIELD RING. LENGTH, 197 IN. DIAMETER, 54 IN. WEIGHT, 120,000 LBS.

through an iron pipe concealed in the capstone of the foundation, up one of the hollow iron columns supporting the bridge or platform across the machine, and thence, along the bridge, to the brushes. From the collector rings it passes under the driver through the shaft, and thence, along one of the ribs inside of the driver, to the field bobbins. The collector rings are built upon a separate cylindrical casting placed above the driver, and securely fixed to the hub of the latter by heavy screws through a flange at its base. The brush-holder rods are held in place by a heavy iron bracket encircling the casting below the collector rings. This bracket rests upon the bridge which spans the machine.

Balancing the Revolving Field.

The longitudinal and transverse sections of the power house and wheel-pit, showing turbines, shafts and generators in place, reproduced on pages 262 and 263, illustrate the relation of these elements in the plant more graphically and exactly than is possible in a mere verbal description. The turbines are so designed that they and the shaft and the revolving part of the dynamo above them are supported upon the water passing through the wheels. By calculation, the force of the water tending to lift the shaft and generator varies from about 149,000 lbs. to about 155,000 lbs., depending upon the amount of water passing through the turbines, which, in turn, depends upon the amount of current which the generator is delivering to the circuits. The weight of the shaft and revolving part of the generator is very nearly 152,000 lbs. The difference between this weight and the upward

thrust of the water is taken care of by the thrust bearing located on the third gallery above the turbines. When the upward thrust of the water exceeds 152,000 lbs., the collars on the steel shaft are pressed upward against the grooves in the bearing in which they revolve, and when the upward pressure is less than 152,000 lbs. the collars are drawn downward by gravity against the grooves in the bearing. This pressure, however, whether upward or downward, in direction, never exceeds 3500 lbs. in amount, and this, of course, puts very little work upon the bearing.

The entire revolving parts of each unit of the plant, therefore, consisting of the turbines, the dynamo field and the shaft, 166 feet in length, constitute a huge top, the weight of which is practically carried upon the water in the turbines. The bearings on the first and second galleries of the wheel pit, and the upper and lower bearings in the generator, are simply guides for the shaft, to keep it in a vertical position, while the thrust bearing on the third gallery acts as a guide, and also carries the relatively small difference between the weight of the revolving mechanism and the upward thrust of the water. The turbines, shaft, and generator field revolve at the high speed of 250 revolutions per minute, and it is obvious that all of the revolving parts, especially the heavy generator field, weighing about 70,000 lbs. and measuring nearly 12 feet in diameter, must be balanced with the utmost accuracy to prevent vibrations which might become dangerous.

The method employed in balancing the revolving element of the generators is illustrated on page 278. A special shaft was placed in the bearings of the machine, and supported at its lower end by a thrust bearing into which oil was pumped at a pressure of about 1000 lbs. per sq. in. This pressure was sufficient to lift the weight of the revolving parts,

COMPRESSED STEEL INGOT WITH HOLE THROUGH CENTER, PREPARATORY TO FORGING.

and the collars on the shaft were separated from the grooves of the thrust bearing by a thin layer or film of oil. A small piece of tool steel was set into the upper end of the shaft, a half sphere or cup being cut in its upper surface, and in this was placed a tempered steel ball,

A FIELD POLE WITH WINDING IN PLACE. WEIGHT, 2800 LBS.

3/8 in. in diameter. A large eyebolt with a similar piece of tool steel, having in its lower surface a cup bearing similar to that at the top of the shaft, was secured in the tapered bearing of the umbrella-shaped driver, to the periphery of which the field ring is bolted. The entire weight of the driver and the ring was thus supported upon the small steel ball.

A casting, clamped to the shaft, served to rotate the driver and ring with the shaft. A section of this casting and of one of the ribs of the driver is shown in the illustration. The steel ball, as will be noted, was placed a very short distance above the centre of gravity of the field and driver, and under these conditions, the driver and ring being free to rock while rotated, a defect in balance was quickly shown. As a matter of fact, in the case of the first generator the driver at first assumed the position indicated by the dotted lines. This was corrected by riveting to the driver a wrought iron plate, the weight of this plate and the distance from the axle of rotation being experimentally determined to obtain not only exact static balance, but also exact running balance.

The driver was first balanced in this manner, independently. The ring was then bolted to the driver, and the two were balanced together as shown in the illustration. It was unnecessary to balance the combination of the driver, ring and field poles since the field poles and bobbins were separately weighed, and their weights adjusted to exact equality, while the positions in which they are bolted to the ring are exactly symmetrical with reference to each other and to the axis of rotation.

Organization of Apparatus in the Power House.

The organization of apparatus constituting the system adopted, that is,

A FIELD POLE.

the inter-relation and the functions of the generators, step-up transformers, step-down transformers, motors, commutating machines and other appa-

ratus, has been described in a general way in the early part of this article. I have also explained the construction of the generators,—the most important unit of apparatus in the plant. It remains now to describe the means adopted for controlling the heavy currents delivered by the generators, and for delivering these currents to the supply circuits which convey them from the power house to the premises of the users of power.

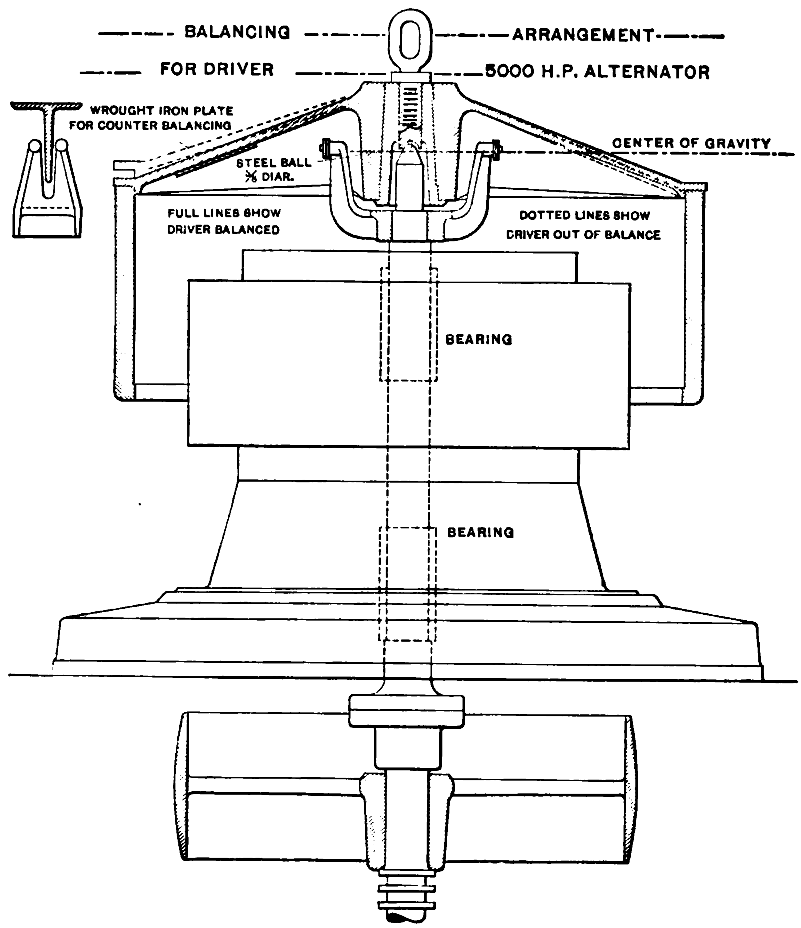
FIELD RING WITH POLES AND BOBBINS IN PLACE.

In deciding upon a plan of station organization, we face, at the outstart, two very serious conditions :—First :—The forces with which we are dealing are, in amount, far beyond the range of experience. Second :—The plan adopted must be capable of almost indefinite extension without radical modification, and without involving loss of symmetry.

We are dealing with energy in units of 5000 horse-power, developed under conditions which are, in many respects, without precedent ; and while, at the outstart, there are to be installed but three generators, the fact must be kept in mind that others will be added to the installation, and that, when the number of generators shall have increased from three to thirty or twice thirty, the organization and means provided for operating them must still be symmetrical and consistent in all its parts. The plan adopted contemplates an arrangement in groups of five generators each. The switching and regulating apparatus, and the indicating and measuring instruments, are concentrated in a swithboard centrally located with reference to each group. Provision is made for cross-connecting the several groups to be ultimately installed in this power house and in other power houses which may be erected on both the American and Canadian sides of the river in order that continuity of service may be doubly assured.

The switchboard is the centre from which the brain and hand of the operator control the mighty forces of Nature which are here compelled to do work,—it is the bridge of the ship. From it, imprisoned energy, aggregating 25,000 horse-power,—electric energy, eager to escape, seeking for the smallest pinhole in insulation, and concentrating instantly at that pinhole, if

found,—must be controlled, combined, subdivided and directed. It is evidently desirable to operate the generators in parallel, this method tending to improve regulation of speed and potential, insuring continuity in the delivery of current to the users of power, and house, and the latter referring to the service which will supply consumers in Buffalo and other distant places. This consideration makes it probable that it will prove convenient and desirable to operate the generators in two sets, for the following reason :—



METHOD OF BALANCING THE DRIVER AND FIELD RING.

minimizing the necessity of opening switches conveying heavy currents of high potential in circuits of very considerable inductance and capacity. But it is also evident that the service will, in the near future, divide itself into two classes, which we may call "local service" and "long-distance service," the former referring to the service which will supply consumers within a radius of a few miles from the power

Distribution of electricity at constant potential is strictly analogous to the methods commonly employed in supplying gas and water. Each consumer has a small, independent circuit through which he draws his supply from the distributing mains, and he may open or close this circuit without in any way interfering with the supply to his neighbours, provided the potential or pressure in the network of mains is kept

TURNING THE FIELD RING IN THE WESTINGHOUSE SHOPS.

constant. For satisfactory service, this last provision is a necessity,—the potential in the distributing mains must be constant. The local circuits at Niagara are supplied direct from the power house, through feeder or supply circuits of comparatively short length, and, consequently, the loss of potential, or drop, as it is technically called, will, in these circuits, not exceed one or two per cent.

The distributing mains in Buffalo, however, will be necessarily supplied from feeders extending from the power house, a distance of about twenty miles, and in these feeders, unless a very high potential be used, the drop will vary from a maximum of, say, five or possibly ten per cent., depending upon the amount of copper in the circuits, down to one-half, one-fourth or one-tenth of these percentages, depending upon whether the current transmitted along the feeders is the full load current for which these feeders are designed, or one-half, one-fourth or one-tenth of the full load current. It follows that at certain times during each day the potential delivered to the long-distance feeders must exceed that delivered to the local feeders by a not inconsiderable percentage, and the readiest means to meet this condition is to operate the generators in two sets or groups, the units constituting each set working in parallel.

When two or more generators work "in parallel," they are so connected that their currents are delivered to a set of large conductors, called "bus bars," just as two engines, belted to the same line shaft, deliver the power which they develop to that shaft. By suitable devices, such as friction clutches or fast and loose pulleys, either engine may be put into service, or shut down without stopping the line shaft; and, in a similar manner, any electric generator of a group may be made to add its current to that of another generator or group operating in parallel with it, or may be shut down without interfering with the

ONE OF THE GENERATOR FOUNDATIONS.

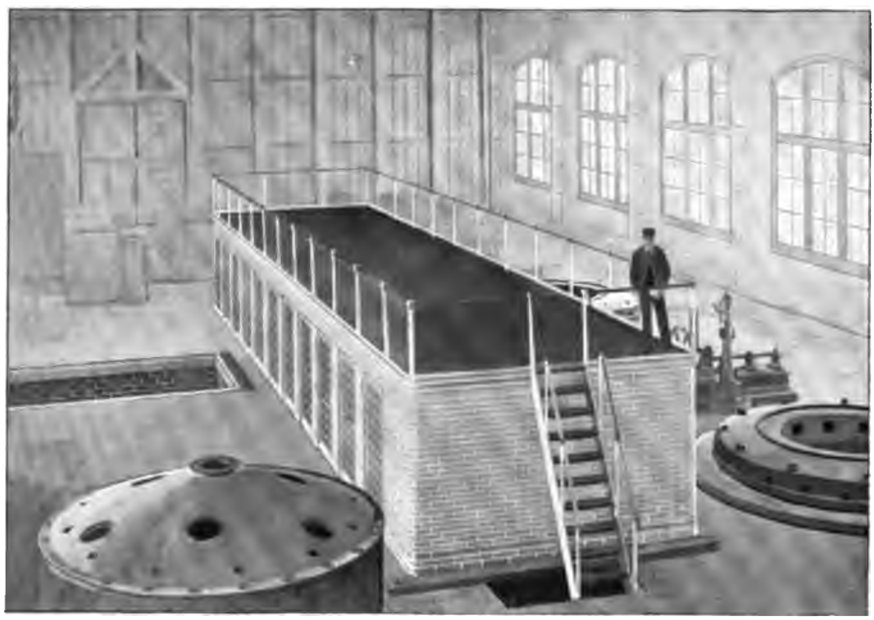
continuity of the supply of energy delivered by the group.

As an alternative to the plan of operating the generators in two groups, they may all be operated in one group, provision being made for adjusting the potential in either the local mains at Niagara, or the distant mains in Buffalo, by special regulating devices. For a limited number of generators this latter plan offers some advantages, but, looking forward to the time when a dozen or a score of generators will be installed, the method of operating in two groups appears preferable.

In the case of transmission to places more remote than Buffalo, it will be necessary to adopt special means for regulating potential in the distributing mains, at least until the time when improved methods of insulating circuits shall make it practicable to employ very high potentials. When that time comes, the drop in the circuits between the power house and the city of Buffalo will become so small that we may treat the Buffalo feeders as local circuits and can supply them with current from the same bus bars that are used in supplying power in the immediate vicinity of the power house; and when the practicability of commercially employing these very high patentials, *e. g.* 25,000 or even 50.000 volts, is demonstrated, transmission to places more distant than Buffalo will naturally be undertaken. Here again the second set of bus bars will be useful. The diagram on page 282 illustrates the connections of generators, generator switches, bus bars, feeder switches and local and long-distance feeder or supply circuits. To avoid complication but two generators and one long-distance and one local feeder are shown. The currents are conveyed from the generators 1 and 2, to the generator switches, S, S'', through insulated cables, each made up of 427 tinned wires. The aggregate section of copper in each cable is 1 sq. in. Through the generator switches the currents from the respective generators pass at the

will of the engineer in charge, to either of the two sets of bus bars A, B. Each set consists of four thoroughly insulated copper conductors, the construction of which will be again referred to. The switches are operated by compressed air, controlled by levers mounted on iron stands placed upon the platform above the switchboard structure within which the switches are located. By them any one of the generators, or any combination of the five generators constituting the group, may be connected to either set of bus bars.

Each switch has two separate and independent air cylinders, by which the two ends of the switch are independently controlled. The construction of the switch is shown in the illustration on page 292. To charge the bus bars A with current from the dynamo, 1, the switch is closed at one end, establishing connections between four points in the horizontal row of terminals, marked *a*, and the four points *b*. To connect the dynamo to the bus bars B, the switch is closed at the other end, establishing metallic connection between the four terminals in the row *c*, and the four terminals in the row *d*. If the two sets of bus bars are to be charged with the same potential we may supply both from the generator, 1, by closing both ends of the switch simultaneously. Similar connections are, of course, possible in the case of the other generators and the bus bars.



THE SWITCHBOARD STRUCTURE.

The feeder switch S′ is similar in construction to the dynamo switches, but the connections are different. So far as the feeders are concerned, it is not necessary that we should be able to connect them to more than one set of bus bars. Until long-distance transmission is begun, either set of bus bars may be used, or both may be charged from the same generator or generators, in which case they will, of course, be charged with the same potential. When additional generators are installed, and long-distance as well as local service is undertaken, as I have said, it will probably be advantageous to operate the

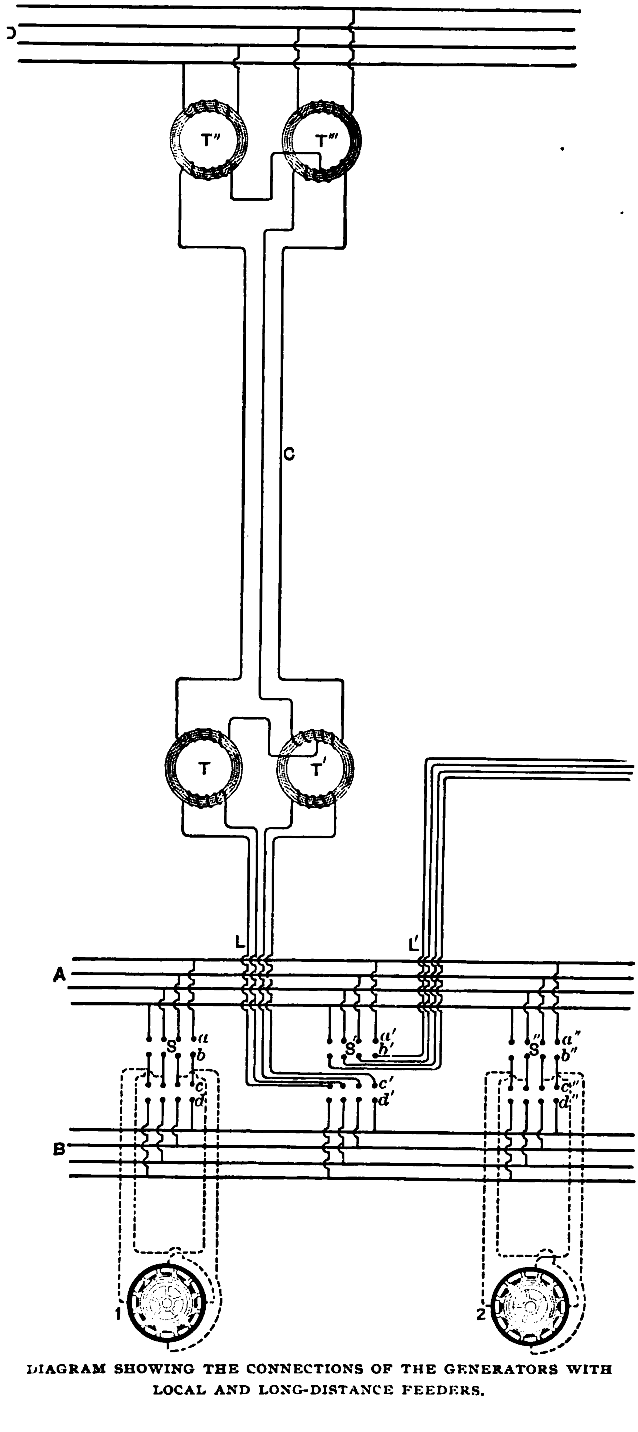
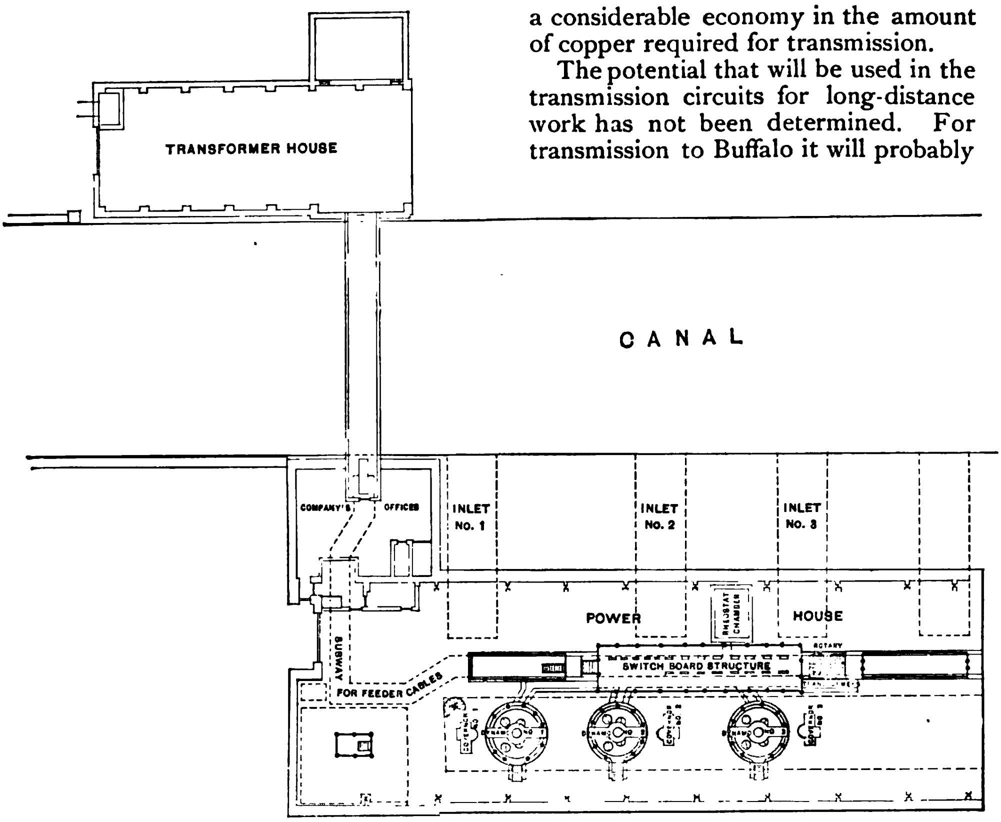


DIAGRAM SHOWING THE CONNECTIONS OF THE GENERATORS WITH LOCAL AND LONG-DISTANCE FEEDERS.

generators in two sets to permit adjustment of potential to compensate for losses in transmission. The respective local and long-distance supply circuits will then be simply arranged for connection through their switches to the local or long-distance bus bars, as desired.

In the diagram on page 282, L represents a supply circuit used for long-distance service, and L′ represents a similar circuit used for local service. In the diagram of the long-distance circuit, T and T′ are step-up transformers, used to increase the potential for transmission, while T″ and T‴ are step-down transformers, located at the distant end of the transmission circuit, for example, at Buffalo or Tonawanda. In the general diagram on page 256 is illustrated the arrangement of circuits in the case of simple two-phase transmission by four wires. The diagram on page 282 shows an arrangement of transformers by which the two-phase currents, delivered by the generators, are changed to three-phase currents in the transmitting circuits, and then changed back to two-phase currents in the local distributing circuits at a distance. This method effects a considerable economy in the amount of copper required for transmission.



PLAN OF POWER AND TRANSFORMER HOUSES.

The potential that will be used in the transmission circuits for long-distance work has not been determined. For transmission to Buffalo it will probably not be less than 10,000 volts, and not more than 25,000 volts. For transmission to greater distances, still higher potentials are contemplated.

The illustration on page 281 shows the structure erected for the switchboard apparatus. It is of white enameled brick, and is 57 ft. 10 in. long, 13 ft. wide and a little less than 8 ft. in height. It is erected directly over the sub-way, as shown in the floor plan on page 283. The top of the structure is of slate sup-

ported upon iron I-beams, and the platform thus formed is surrounded by a neat brass hand-rail. The sub-way beneath the switchboard is spanned at suitable distances by iron I-beams, to which the dynamo and feeder switches are bolted in place. The cables passing from the generators through ducts beneath the floor line are connected to the generator switches, while the outgoing cables, constituting the feeder or supply circuits, drop directly from the feeder switches into the subway. Iron standards are secured to each side of the subway by expansion bolts. They are placed at intervals of about 4 ft., and adjustable iron brackets set into these standards support the lead-sheathed cables passing through the sub-way and bridge to the transformer house on the east bank of the canal.

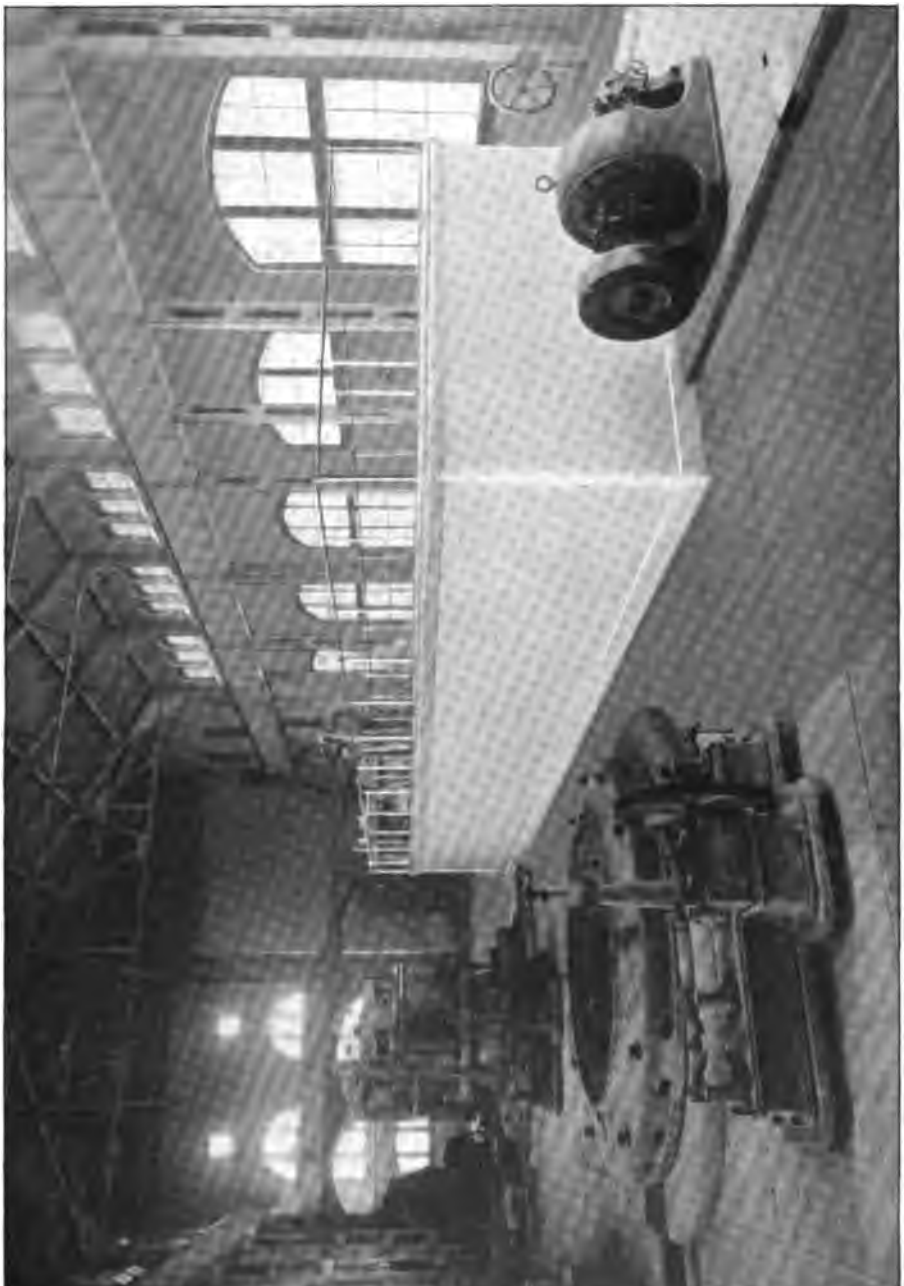
The drawing on page 283, showing the floor plan of the power house, bridge and the transformer house, will make clear the position of the switchboard structure with reference to the first three generators and the sub-way. Additional generators will, in due time, be erected in line beyond the generator marked "Dynamo, No. 3," and the switchboard structure is designed to accommodate all instruments and switches needed in connection with the first five generators.

The organization of the switchboard apparatus and the general features of the construction of the essential elements will be best understood by reference to the illustration on page 286, which is reproduced from the official drawing. The upper part of the illustration at the reader's right hand is a front elevation of the stands which carry the instruments for the several generators and for the exciters, and also shows one of the lever stands for the feeder circuits. Beneath the floor line of the switchboard platform is seen one set of bus bars in connection with an end elevation of the generator and feeder switches. A plan of the switchboard platform is also given in the illustration on page 288, a part of the platform being cut away to show a plan of one generator switch and one feeder switch. On page 286, again, is shown a plan of the rheostat chamber and sub-way for the cables, and just above this, a section through the switchboard, sub-way and rheostat chamber, at right angles to the direction of the sub-way, is given.

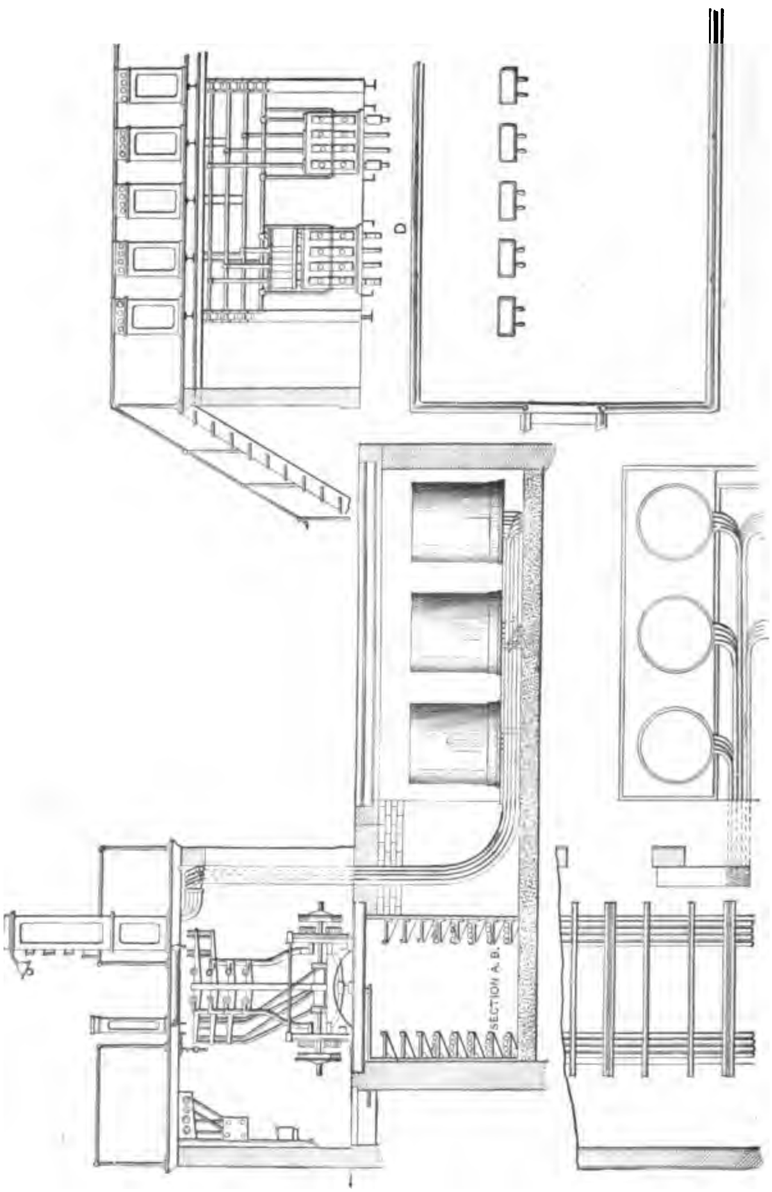
The essential elements of the switchboard apparatus are,—the generator and feeder switches, the bus bars, the switching and safety devices for the exciting currents, the rheostats for controlling the generator fields, and the indicating and measuring instruments. As shown by the plans, the switches and bus bars are located within the switchboard structure. Upon the switchboard platform are erected the instrument stands, one for each generator, two for the rotary transformers, and one for the engine-driven generator, temporarily used as an exciter, and in front of each instrument stand is placed a cast-iron stand, about 30 inches in height, carrying the levers which control the admission of air to the switch cylinders, and a wheel by means of which the rheostats are controlled.

Each of the lever stands used for controlling the large generator switches carries also levers for opening and closing the field circuit of the corresponding generator, and a hand wheel by which the rheostat resistance in the field of the generator is adjusted. The rheostats are located in a special chamber below the floor line of power house, the face-plates being located in the bases of the instrument stands. Connection between the face-plates and resistance coils of the rheostats is secured by insulated cables of suitable section. The compressed air used in operating the switches comes from a compressor direct, driven by a Worthington water motor. This compressor is located at the bottom of the wheel pit, and supplies air to a large cylindrical reservoir from which pipes are led to the various switches. The pressure used is 125 pounds per square inch.

Engineers, not familiar with the possibilities of electricity, will be impressed by the fact that the currents actually measured are not the heavy currents traversing the cables within the switch-



ONE END OF THE POWER HOUSE.



THE ORGANIZATION OF THE SWITCHBOARD APPARATUS.

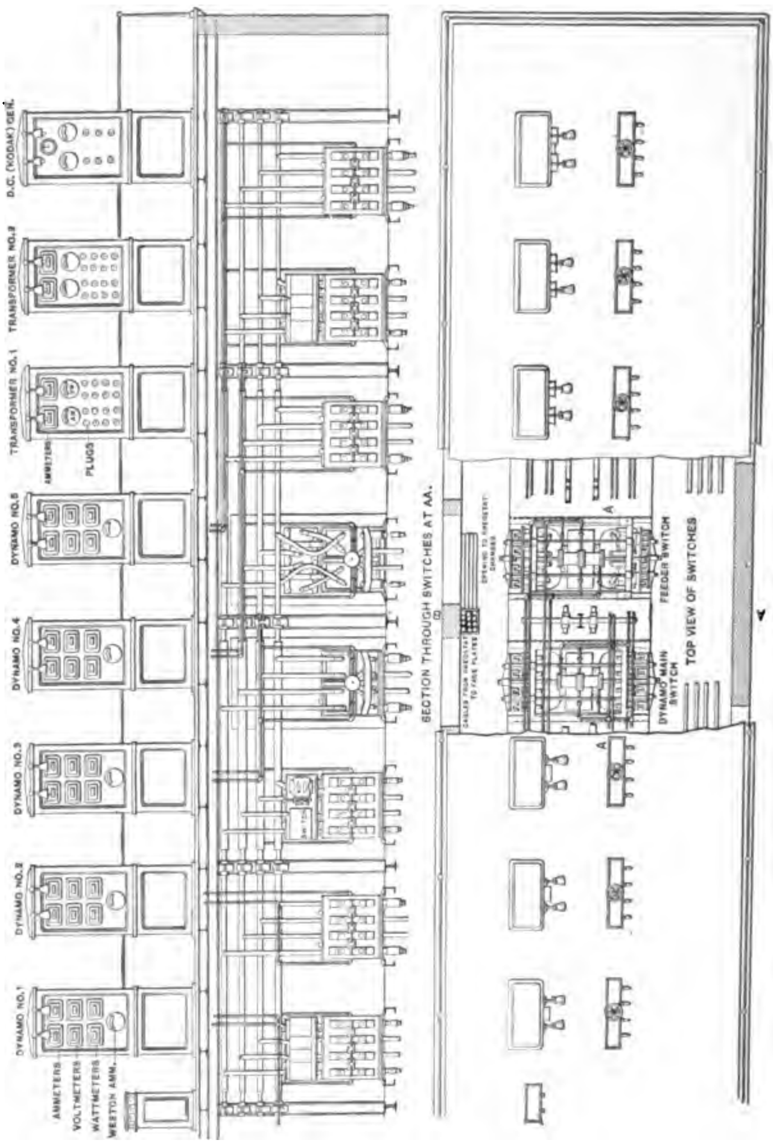
board structure, but are derived currents, bearing a known relation to the heavy currents delivered by the generators. They are small in quantity and absolutely harmless. The operator, standing upon the switchboard platform, cannot possibly touch a circuit which is in the slightest degree dangerous. The currents measured are obtained by means of transformers located inside the switchboard structure, the ratio of their winding being such that for every 50 ampères flowing in the main circuit, a current of 1 ampère is supplied from the secondary of the transformer to the measuring instruments. Currents to the respective voltmeters are supplied from transformers, the primaries of which are connected across the generator circuits. For the wattmeters both series and shunt connections from the generator circuits are needed, and these are obtained from the transformers used for the voltmeters and ammeters.

To measure energy, current and potential in each phase of each generator, two converters, an indicating wattmeter, an ammeter and a voltmeter are employed. The energy required by these devices amounts, as a maximum, to about 30 watts—that is, $\frac{1}{25}$ horse-power. It is an extraordinary illustration of the facility with which electricity is accurately measured that we should be able thus to determine energy varying from 25 horse-power to 2500 horse-power by means of measuring devices, accurate throughout their range within one per cent., and requiring for their operation not more than $\frac{1}{20}$ horse-power.

The instrument stands are boxes or cabinets, constructed of iron and marble, the front of each, above the pedestal, being formed of a single slab of polished Italian marble, 1¾ inches thick, 30 inches in width and 45 inches in height. Each stand occupies a floor space of 38 inches by 20 inches and is 7 feet in height. Sliding doors at the back give access to the measuring instruments. The marble front of the stand is pierced by six rectangular openings, and the instruments are secured to the marble in such a way that the front of each, with its scale and index, projects through the marble to the front of the stand.

The engraving on page 289 illustrates one of the alternating current ammeters, as viewed from the front. The indicating wattmeter and the voltmeter are similar in appearance. The fronts are finished in oxidised brass. These instruments, and the integrating wattmeters, used in connection with feeder circuits (not located upon the switchboard platform), comprise a remarkable group of measuring instruments recently invented and designed by Mr. Oliver B. Shallenberger, Consulting Electrician of the Westinghouse Company. As they were primarily designed with special reference to the Niagara installation, they are designated the "Niagara type" by the Westinghouse Company. Their sphere of usefulness, however, will be as wide as the applications of alternating currents. They depend for their action upon the induction of currents in a movable closed secondary circuit, and all operate to a certain extent upon the same general principles, specifically developed in each case to attain the object desired. They are extremely simple in construction, the parts are few and comparatively massive, and yet the instruments are capable of giving very accurate results. They are guaranteed by the Westinghouse Company to be correct within one per cent.

In each instrument a thin aluminium disc, stiffened by a flange around its edge, constitutes the movable element, in which eddy currents are induced by currents traversing coils placed above and below it. The relation of the induced currents in the disc and the inducing currents in the coils is such that the disc tends to rotate. In the wattmeter the tendency is proportional to a function of the energy traversing the inducing circuits, and these currents come from a converter located beneath the platform, and, in turn, are proportional to the energy in one of the gen-



SOME DETAILS OF THE SWITCHBOARD.

erator circuits, which is the energy to be measured. The tendency to rotate is resisted by a torsion spring, and the currents turn the disc, overcoming the resistance of the spring through a certain angle. This angle depends upon the relative strength of the twisting moment, due to the currents and the resisting force of the spring, and the position of the disc, with reference to its position when no current traverses the coils, becomes a measure of the energy. The scale is attached to the circumference of the disc, and depends from it much as the field ring of the generator depends from the driver. This scale is carried with the disc, from its zero position, through an angle depending upon the current measured, and the instrument being once carefully compared with a standard and the scale properly marked, the energy can be determined by taking the reading of this scale opposite the index, which is always fixed in position. In the illustration on this page the index will be seen in the centre of the rectangular glass window, and, immediately behind it, an arc of the circular scale.

The ammeter, which measures the strength of the current, and the voltmeter, which measures the potential, resemble the indicating wattmeter in the fact that they are based upon the same principles, and they are also similar in general features of construction. The methods employed to obtain the proper phase relations of the currents in the inducing circuits and in the disc are very ingenious and, to the electrician, interesting. But this is not the place to describe them in detail.

The ammeters, which measure the currents in the fields of the generators, were furnished by the Weston Instrument Company, of Newark, N. J., and are of their well-known type, in which the current actually measured by the instrument is that which flows through a circuit connected in shunt to a resistance which is placed in the circuit traversed by the current to be measured.

All of the currents measured by the instruments located in the instrument stand are supplied through insulated conductors of small section, which convey the small derived currents from converters or from the terminals of resistances placed beneath the switchboard platform. Each generator instrument stand carries, in addition to the instruments already described, a phase indicator, by means of which the attendant or the engineer in charge, who desires to connect a generator in parallel with another generator or group of generators, determines the proper time for closing the switch.

The instruments provided for the stands belonging to the rotary transformers used as exciters, are not the

AN ALTERNATING CURRENT AMMETER, NIAGARA TYPE.

same as those provided for the generator instrument stands, and they also differ from the instruments provided for the stand belonging to the temporary engine-driven exciter. They comprise two Shallenberger alternating-current ammeters of the Niagara type and a direct-current ammeter and voltmeter made by the Weston Instrument Company. A number of plug contacts are provided, by means of which the ratio of conversion of the static transformers which supply current to the rotary transformers may be adjusted.

The construction of the bus bars is, in several respects, remarkable, the magnitude of the quantities dealt with again making it necessary to devise methods of construction outside the range of experience. As has been said, two sets of bus bars are provided, but it

is, of course, conceivable that under certain circumstances it may be desirable to cut one set out of service and control the output of five generators through the other set. By arranging the generator switches and feeder switches as shown in the illustration, in such a way that the former, through which current is delivered to the bus bars, alternate with the latter, through which current is drawn from the bus bars, the maximum current which it is necessary to convey through any section of the bus bars becomes that supplied by three generators. This is equivalent in each bar to about 3000 ampères, and, assuming a current density of 1000 ampères per sq. in., would require a section of about 3 sq. in. in the bus bar. The potential of the currents may be as high as 2400 volts.

A short-circuit might obviously be very dangerous, and this fact, in connection with the fact that at certain times the atmosphere of the power house is liable to carry a considerable amount of moisture, ready to be precipitated upon metallic surfaces, points to the desirability of insulating the bars. To insulate them in the most satisfactory manner, rounded surfaces are necessary, but in a round solid conductor, 3 square inches in section, nearly 2 inches in diameter, two other difficulties must be faced : First, the surface from which the heat, due to resistance, must be radiated, is small as compared with that obtained by using flat bars or straps of equal section ; and, second, an alternating current in such a conductor will not distribute itself uniformly, but will seek the surface, leaving the copper at the centre relatively idle and ineffective.

These difficulties have been successfully overcome by the construction adopted. From the middle each bar tapers toward the ends. The middle section consists of a copper tube of about 3 inches outside diameter and 2 inches inside diameter. Into this, at either end is screwed a tube, the outside diameter of which is approximately 2 inches, while its inside diameter is about $1\frac{1}{8}$ in. Into the other ends of each of these tubes, in like manner, a copper rod $1\frac{1}{8}$ inch in diameter is screwed. The offsets or connections from which short lengths of cable convey current to or from the several switches, are clamped to the bar thus formed, all surfaces being rounded. The entire bar with offsets is then insulated with very high-class rubber insulation. These bars were constructed by the Brown & Sharpe Manufacturing Company, of Providence, R. I., U. S. A., according to the designs of the Westinghouse Company, and were insulated by the India Rubber and Gutta-Percha Insulating Company, of New York, the method employed being that covered by the Habirshaw patents. The insulation consists of alternate layers of pure Para gum and vulcanized rubber, two layers of each being used, and the outer layer of vulcanized rubber protected by a special braided covering chemically treated to make it non-combustible. Similar insulation is used for the cables between the generators and the switches and for the connections between the bus bars and switches.

A section of the Habirshaw cable is reproduced on the opposite page. The illustration is very nearly the exact size of the cable. The makers guarantee that the insulation of cables and bus bars, erected in place, shall stand an alternating current potential of 10,000 effective volts between copper and earth. Samples submitted and tested in the laboratory of the Westinghouse Company successfully resisted the application of potentials exceeding 40,000 volts.

The calculated losses in a set of four bus bars conveying the full output of five generators, 25,000 electrical horsepower, are less than 10 horse-power. The radiating surface is, of course, considerably greater than it would be in the case of solid circular bars of equal section. At the ends of the bars, where the section is about 1 sq. in., the current is that coming from one generator only, and in a bar of this section the tendency of the current to seek the surface is negligible. In that part of the bar which has an outside diameter of 2 inches the current con-

veyed may be that coming from two generators, and the tendency to seek the surface would be appreciable in a solid circular conductor of equal section, while in that part of the bar which is 3 inches in diameter and which may be called upon to convey current from three dynamos, it would be very considerable. The use of the tubes instead of solid bars gets rid of the idle copper at the centre of the latter, and at the same time increases the ratio of radiating surface to section of conductor.

The construction of suitable switching devices for circuits conveying 5000 horse-power at a potential of 2000 volts is a serious problem. To be sure, the dynamos will be operated in parallel, and by proper adjustment of the field charges of the generators and the gates controlling the turbines, the current traversing the dynamo switch at the moment of opening or closing the circuit can be reduced within moderate limits. But there is always the chance that something may go wrong; the operative may make a mistake, or something else may happen, and it was, therefore, deemed necessary to construct a switch capable of opening without damage to itself or other apparatus, circuits conveying 5000 horse-power. The Westinghouse Company accordingly inaugurated a series of experiments, and detailed several expert engineers to thoroughly study the subject. The result of their work is illustrated on page 292. The opportunity has not yet been afforded to thoroughly test this switch in commercial service, but shop tests, carried out under conditions approximating to those which will be met in practical operation of the plant at Niagara, indicate that it is capable of switching very heavy currents without damage to itself, and without dangerous rise of potential.

Current for exciting the fields of the generators is obtained directly from rotary transformers, which, in turn, are supplied with alternating current from the generators, static transformers being interposed to reduce the potential. During the period of construction exciting current is also derived, when necessary, from a 75 kilowatt direct current generator driven direct by a Westinghouse compound engine. This generator and engine, together with the boiler plant for the latter, are located in a small temporary building at a distance of about 200 yards from the power house. The engraving on page 293 illustrates one of the two rotary transformers installed, and their location in the power house is indicated in the floor plan on page 283. These transformers are of 200 kilowatts output each.

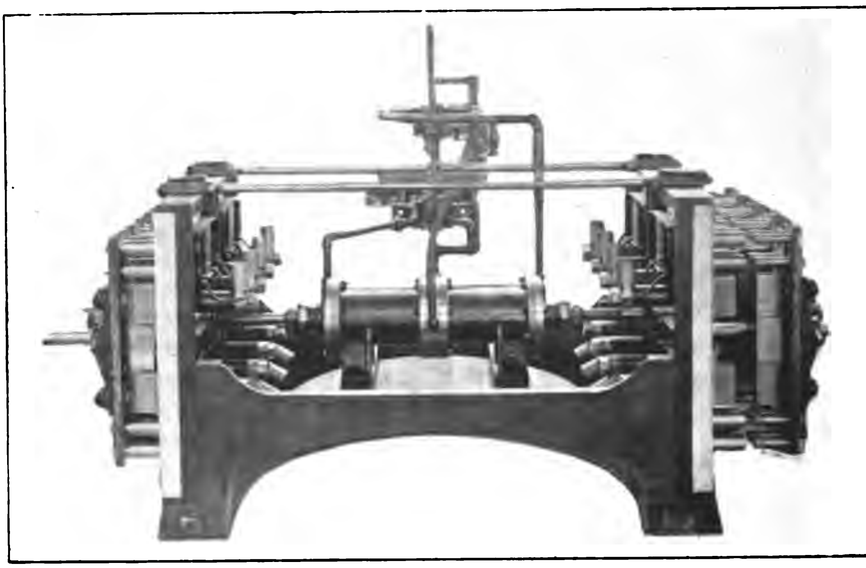
As will be seen in the illustration of

A SECTION OF THE HABIRSHAW CABLE.

the complete machine, on page 259, the shaft carries a commutator at one end of the armature and a four-ring collector at the opposite end. Alternating current, at about 125 volts potential, is delivered to the collector from the secondary terminals of the static transformers, one of which is illustrated on page 294. From the commutator end of the rotary transformer, direct current, at a potential approximating 175 volts, is delivered to the fields of the generators, the field rheostats being interposed in these circuits to permit adjustment of the current flowing in each field.

The armature winding is of the closed circuit type, and each of the ring collectors is connected to a certain point in the same winding from which current is delivered to the commutator. The machine, in operation, runs as a

synchronous motor, driven by the two-phase alternating current, and delivers from the commutator continuous current, just as it would do were it driven as a generaror by a turbine or an engine. The fly-wheel at the end of the shaft is used to give steadiness of speed and to prevent what is sometimes called "pumping;" that is to say, unequal angular velocity at successive stages in a revolution of the armature, caused by the flow of idle current between the generator and the rotary transformer.



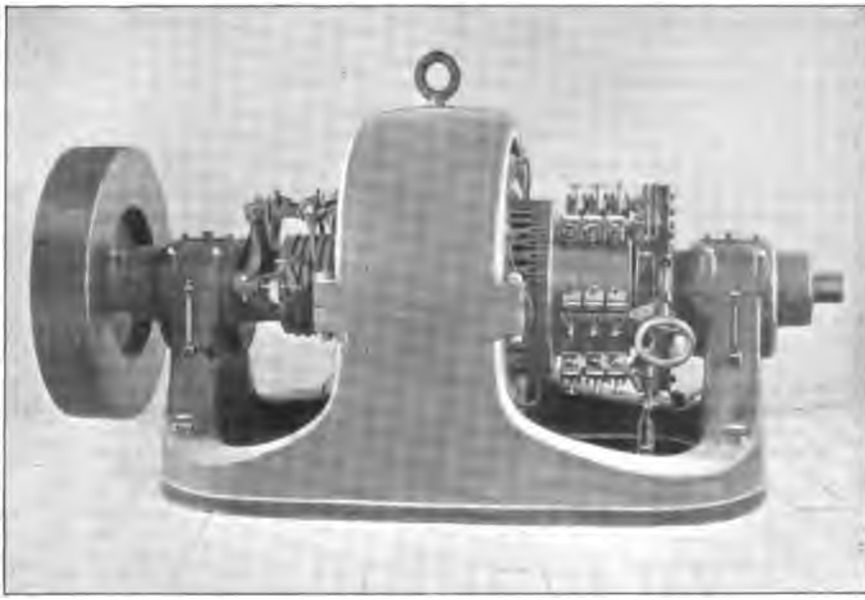
ONE OF THE MAIN SWITCHES.

Two static transformers, each capable of delivering 100 kilowatts each, are used to supply alternating current to each rotary transformer. They are placed in cylindrical boxes of boiler iron, and are immersed in oil. This secures an extremely thorough insulation. The oil is kept cool by water, which circulates through a spiral of galvanized iron pipe, fitting closely to the inside of the cylindrical box. Each box is provided with an oil gauge by which the height of oil may be determined. Provision is made for readily drawing off the oil at the bottom of the box in case of necessity. The transformer, the box, and the spiral of pipe through which the water circulates are shown on page 295.

Before the generators were erected in the shops of the Westinghouse Electric and Manufacturing Company, at Pittsburgh, careful tests were made of the materials used in the construction of the various elements of the machines. Of these, the tests of the physical properties of the shaft, field ring and driver have been referred to. The special means adopted for balancing the revolving parts of the generator have also been described. Among other tests, the following are of especial interest:

Tests of the Magnetic Qualities of the Field Ring.

Two samples of steel, cut from the edge of the rough-forged ring before it was turned, were tested by the permeameter method to obtain what is technically known as the B-H curve; that is, the ratio of induction to magnetizing force for various values of the latter. The B-H curve was also determined by a modification of the so-called "ring method," the entire field ring being used for this purpose. This very beautiful and interesting experiment



A 200 KILOWATT ROTARY TRANSFORMER USED AS AN EXCITER.

was suggested by Mr. Chas. F. Scott, electrician of the Westinghouse Electric and Manufacturing Company, and carried out under his direction.

All the measurements are illustrated graphically in the chart on page 297. Curves A and B are respectively the B-H curves for wrought-iron and cast-iron, as determined by Dr. John Hopkinson of London, and are here given for purposes of comparison. Curve C is the B-H curve for nickel, as determined by Prof. J. A. Ewing. Curves D and E are determined by permeameter from samples cut from the edge of the ring. Curve F was determined by the ring method, using the entire field ring. The very high values of the induction, for all except very low magnetizing forces, are remarkable.

The tests by the ring method indicate higher values of the induction for moderate magnetizing forces than were obtained by the permeameter. The former is the more reliable method, and curve H undoubtedly represents very closely the true relation of induction and magnetizing force in the field ring of the first generator. The permeability of the field ring is, therefore, considerably higher than that of standard wrought iron.

ARMATURE OF THE ROTARY TRANSFORMER.

For the purpose of balancing the driver and field ring, and to make mechanical and electrical tests as complete as was practicable in the shops where no 5000 horse-power engine was available to drive the generators under full load, each machine was erected in such a manner that the weight of the

revolving element was carried upon a collar or thrust bearing at the bottom of the shaft. Into this bearing oil was forced by a pump, at a pressure approximating 1000 pounds per square inch, the result being that the collars on the shaft and the corresponding grooves in the bearing were thoroughly lubricated. The oil was kept in circulation so that it might not become excessively heated.

That the friction in the bearing was reduced within very moderate limits was demonstrated during some of the later tests, when, the driving belt coming off the pulley suddenly when the machine was running at about 250

A 100 KILOWATT TRANSFORMER.

revolutions per minute, the field continued to revolve for thirty-nine minutes by reason of its own inertia.

Determination of the Potential Curve.

As is now pretty well understood by those who are in any way interested in engineering, the potential at the terminals of an alternating current generator varies from zero to a positive maximum value, then to zero, then to a negative maximum value, and then to zero again, this cycle being continuously and rapidly repeated, in the case of the Niagara generators twenty-five times per second. One half of such a cycle is graphically represented by the chart on page 298, in which the solid line is the curve of potential at the terminals of the first generator, as experimentally determined. The dotted line is a sine curve, representing an electromotive force of equal effective value. Horizontal distances, measured along the base or zero line, represent time, while the vertical distances, measured from the base line to the potential curve B, represent difference of potential at the generator terminals. At any given instant, represented by a certain point on the base line, the difference of potential is proportional to the vertical distance from that point to the curve.

In the determination of the form of the potential curve at the terminals of the first Niagara generator, a method, suggested by Mr. B. G. Lamme, of the engineering staff of the Westinghouse Electric and Manufacturing Company, was adopted, and carried out as follows: The machine being set up, as above described, a steel cable was secured to the outside of the field ring, about which it was wound to the extent of a half-dozen turns. The free end of the cable was then secured to a vertical shaft placed in a boring mill. The latter, being revolved at slow speed, the cable was wound upon the shaft, and the field of the generator was slowly revolved as the cable unwound from the field ring. In this way an extremely slow speed (about one revolution in five minutes, or one cycle in fifty seconds) was obtained.

A field charge which, at 250 revolutions per minute, would induce an electro-motive force of 2500 volts in the armature, would, at this speed, induce about 2 volts in the armature circuits. Voltmeters, capable of reading accurately to $\frac{1}{100}$ of a volt, were connected directly across the terminals of the armature, and, as the field revolved, readings were taken at intervals of three

seconds, these intervals being timed by an observer, while two others read the voltmeters, and two assistants recorded the readings. This test was repeated many times with very close agreement in the results. It is due to Mr. Scott, Mr. Lamme and Mr. McLaren, of the technical staff of the Westinghouse Company, to say that the results, when plotted to the same scale as the theoretical curve which they calculated before the test was made, can scarcely be distinguished from the actual curve determined by experiment.

By the efficiency of the generator we mean the ratio of electrical output to mechanical input; that is to say, the quotient obtained by dividing the amount of energy delivered to the circuits by the generator, by the energy delivered to the shaft of the generator at the top of the long shaft which connects the generator and the turbine. This quotient is expressed as a percentage of the input. The difierence between the input and output of energy is represented by the various losses in the generator.

These losses are mechanical, electrical and magnetic. The mechanical losses are those due to air friction of the revolving parts of the generator, and the friction of the two bearings which guide the generator shaft. The electrical losses are those due to the main or primary current traversing the armature conductors, the exciting current in the field winding, and eddy currents which may be set up in the armature conductors, in the core of the armature, in the field poles and in the field bobbins. The magnetic losses are those due to the magnetization of the core of the armature, which is, of course, alternating in sign, and to fluctuations in the magnetization of the field. Not all of these various losses can with convenience or accuracy be segregated, but fortunately, practically all that are of special importance can be measured. Tests were, therefore, made at the Westinghouse factory which determined the efficiency of each machine with a very fair degree of accuracy. They were made with great care, and in the case of the first generator all important measurements were repeated many times. This is not the place for a complete statement and discussion of the tests made, which, in itself, would be as long as this entire article, but the methods employed and the results obtained may be briefly summarized.

DETAILS OF THE 100 KILOWATT STEP-DOWN TRANSFORMER.

As the generator was erected in the shops, the revolving element was sustained, as already stated, by a collar or thrust bearing. A direct current motor, capable of delivering 200 horse-power, was used to drive the generator, the motor being turned upon its side, so that the shaft, supported upon a thrust bearing, was vertical, and, therefore,

THE AMERICAN FALLS AT NIAGARA.

parallel to the shaft of the generator. The field of the direct current motor was independently excited, and readings of the current and potential, delivered to its armature from a direct current generator, driven by an engine, were taken in a series of tests, which were repeated several times during a period of about two weeks. The results show that when the field of the generator was not charged by exciting current, it was necessary to deliver to the motor 76 horse-power to drive the what this belt friction, and the increased friction in the bearings, due to tightness of the belt, amounted to could not be easily determined, nor was any attempt made to segregate the loss in the thrust bearing from the other losses.

This loss in the thrust bearing is not properly chargeable to the generator, since the machines, as erected at Niagara, have no thrust bearing above the point in the shaft where the power is delivered to the generator. It can safely be said, therefore, that at Niagara

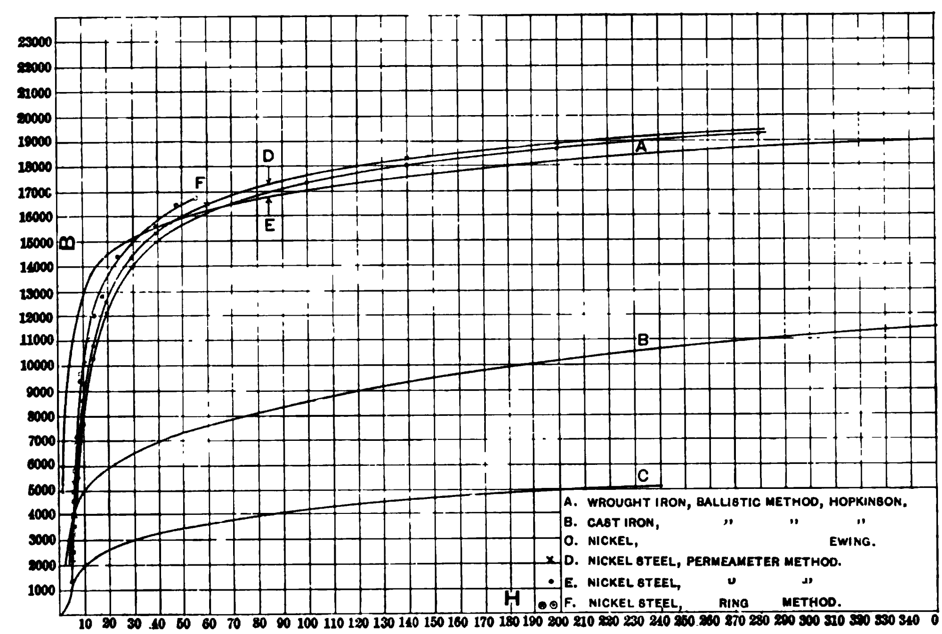


CHART SHOWING THE MAGNETIC QUALITIES OF THE FIELD RING.

generator field at a speed of 250 revolutions per minute. The belt connecting motor and generator being taken off, 26 electrical horse-power were required to drive the motor at the same speed as before. The difference between these two quantities, or 50 horse-power, represents the mechanical friction in the generator, made up of air friction, the friction of the two bearings which guide the shaft, the friction of the step-up or thrust bearing at the bottom of the shaft, and also the loss in the belt, which was necessarily kept very tight. Just the total mechanical losses in the generator will be less than 50 horse-power, —that is, less than one per cent. of the power required to drive them.

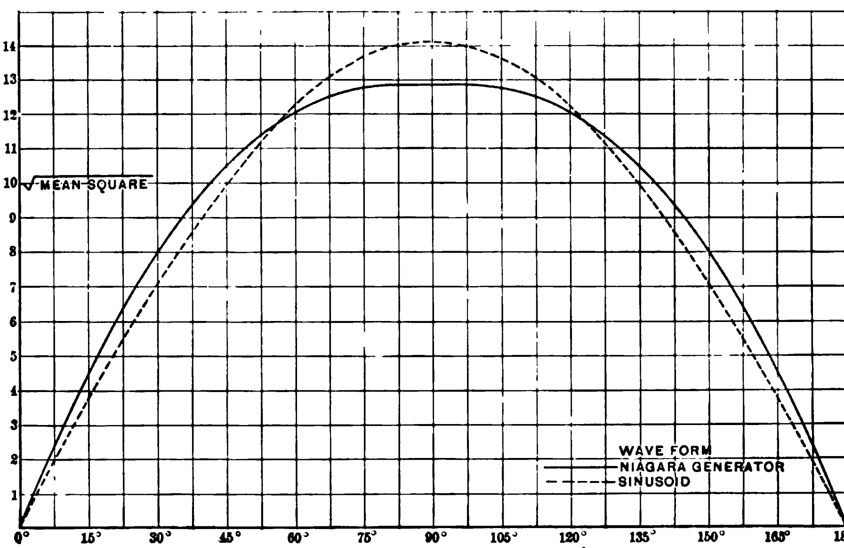
The determination of the amount of energy represented by the current which excites the field of the generator is easily made. The method employed was to charge the field, beginning with a very small current, and increase this by successive steps until the potential at the terminals of the armature, at a speed of 250 revolutions per minute, approximated 3000 volts, taking at each

step simultaneous reachings of the current in the field, the potential at the field terminals, and the potential at the armature terminals. The field current was then gradually reduced, simultaneous measurements being taken as before of the current in the field, the potential at the field terminals, and the potential at the armature terminals. In this way the field current required to induce in the armature, without load, any given electromotive force not less than 500 volts and not greater than 3000 volts, was determined. From this the field current which corresponds to any armature potential when the generator is loaded,—that is, when the armature is delivering current,—can be determined with close accuracy by calculation.

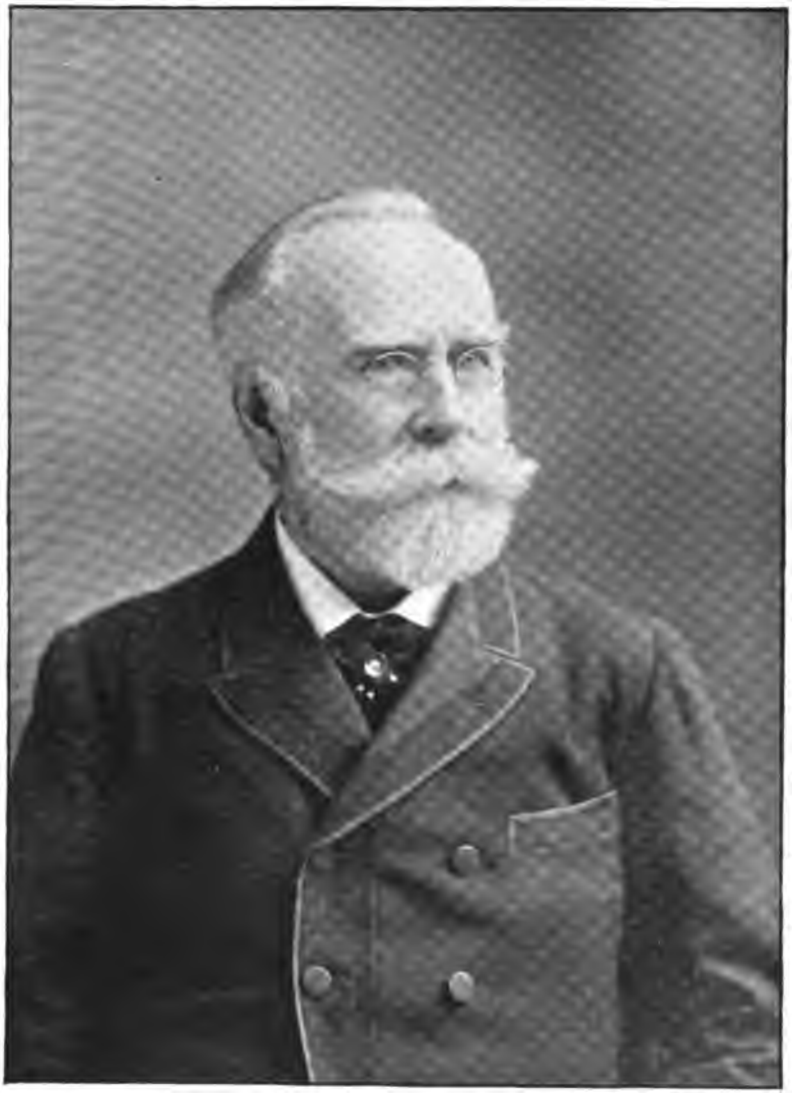
With some types of machines this would not be so easily done, but in these generators the relations existing between the armature and field are similar to those which exist in many of the large generators employed in street railway service, and in making the calculation, therefore, we are not far removed from the safe basis of experimental fact. In this way it was determined that under conditions which will exist at Niagara, the field current in each generator under full load will in no case exceed 15 horsepower.

The next loss to be determined is that due to the magnetization of the armature core. This is made up of two factors, but for our purpose, these need not be differentiated from each other. The test was made as follows : The generator being driven at a speed of 250 revolutions per minute by the direct current motor, measurements of the electric energy delivered to the latter were made coincidently with measurements of the potential at the terminals of the generator armature. As the current in the field of the generator is varied, by adjusting resistance in its circuit, the magnetization of the armature, of course, varies, and the potential at its terminals is a measure of the magnetization, or, more strictly, induction in the armature core.

As the magnetization increases, more power is required to revolve the field, the difference in the power delivered by the motor to the generator for any given potential at the armature terminals (that is, for any given degree of magnetization), and the power required to drive the field at the same speed with



THE POTENTIAL CURVE FOR ONE OF THE GENERATORS.



Coleman Sellers

DR. COLEMAN SELLERS, one of the best known engineers on both sides of the Atlantic, is the consulting engineer of the Cataract Construction Company, and is also president and chief engineer of the Niagara Falls Power Company.

D'Courcy May -

DE COURCY MAY was the engineer and general superintendent of the Cataract Construction Company during the installation of the wheelpit machinery.

no magnetization being accounted for by the core loss. As already stated, the energy required to drive motor and generator, as determined in the case of the first machine, is 76 horse-power, and by subtracting this amount from the amounts required to drive the generator with any given magnetization in the core, we have a closely accurate measure of the loss.

In this way it was determined that the amounts of power delivered to the motor, corresponding to potentials at the armature terminals varying from 2000 to 2400 volts, were as follows :

2000 volts	121 − 76 = 45	horse-power
2200 "	130 − 76 = 54	"
2400 "	141 − 76 = 65	"

Were the armature in service, delivering currents representing the full output of the machine, the distribution of the magnetic lines in the armature core would be somewhat, but not very radically different, and consequently these measurements do not tell us exactly what the loss in the core will be under conditions of actual service. But, making a fair allowance for an increased loss due to this and other minor causes which may make themselves felt in the commercial operation of the generator, it would seem safe to say that the loss in the armature core, operating at 2100 volts, which is about the voltage at which those generators supplying local service will be operated, will not exceed 60 horse-power.

The loss due to the current in the armature conductors could not be accurately determined from tests in the shop. This loss, however, is easily calculated with close accuracy from measurements of the resistance of the armature conductors and the known value of the full load currents which they will carry in service. Disregarding possible eddy currents in the conductors, which, from the construction, should be almost negligible, calculations show that the loss in the armature conductors under full load will not exceed 30 horse-power. Theory indicates that other losses, with the possible exception of eddy currents in the field poles, will be so small as to be practically negligible, and including the loss in the field poles, which could not be readily determined, their amount will not be sufficient to materially affect the efficiency of the generator.

To sum up the mechanical, electric and magnetic losses, when the generator is delivering current at 2100 volts, we have roughly the following:

Maximum loss in field copper	15	horse-power
Loss in armature core	60	"
Loss in armature conductors	30	"
Total	105	"

To arrive at the actual efficiency of the generator we must add to this the losses due to air friction and friction of the bearings, but the tests do not indicate to what these amount, except that with the loss in the thrust bearing used during the shop tests they did not exceed 50 horse-power. With the losses in the thrust bearing charged against the generator (which is, of course, unfair to the machine) we have for the total mechanical, electric and magnetic losses 155 horse-power. In order that the generator shall deliver 5000 horse-power to the circuits it is, therefore, necessary that 5155 horse-power be transmitted to it through the shaft. Dividing 5000 horse-power, the output, by 5155 horse-power, the assumed input, we have almost exactly 97 per cent. From all this it appears perfectly safe to say that the generators, under the conditions of commercial service, will, at full load, operate at an efficiency exceeding 97 per cent. At the time of writing this, the tests of the generators as erected in the power house at Niagara are not yet completed.

The description of the electric generating plant in the foregoing pages is necessarily incomplete. Much that would interest scientific specialists is omitted or merely glanced at, and on the other hand, space and time have not permitted the attempt to elucidate statements which, to those not familiar with electric work, must appear more or less obscured by technical phraseology. This I cannot hope to amend.

The tests of the first 5000 horse-power unit are now in progress, and success is assured. When, on the

morning of April 4th, 1895, Mr. Rudolphe Baumann, the Swiss engineer, who has for several years devoted his skill and energy to perfect the hydraulic plant, gently moved the hand wheel which controls the first turbine, the field of the generator began to revolve, noiselessly, irresistibly, testifying to the skill and painstaking effort of the civil, hydraulic, mechanical and electrical engineers, whose combined efforts, directed by the splendid enterprise of the Cataract Construction Company, have united in producing a 5000 horse-power unit of machinery, capable of transforming the energy of falling water to electric energy, live, vibrant, needing only suitable conductors to guide it across miles of country, to places where it may turn the wheels of a thousand mills and factories.

The Niagara generators were constructed by the Westinghouse Company, following, as regards mechanical form, the type of machine proposed by the engineers of the Cataract Construction Company. This was fully described by Prof. George Forbes in a paper read in November, 1893, before the British Institution of Electrical Engineers. The auxiliary electric apparatus, including exciters, switching devices, measuring instruments, etc., were designed and constructed by the Westinghouse Company, assisted, as to the bus bars, by the Brown & Sharpe Manufacturing Company, of Providence, R. I., U. S. A., and the India Rubber and Gutta Percha Insulating Company, of New York.

Among those who have been particularly prominent in the work are: Mr. Albert Schmid, general superintendent; Mr. C. F. Scott, electrician; Mr. Philip Lange, superintendent; Mr. O. B. Shallenberger, consulting electrician; Mr. B. C. Lamme, Mr. E. C. Means, Mr. H. P. Davis; Messrs. Sigfried, Wright, Boegel, W. F. Lamme, Beinitz, Alberger, Mirault, Friedlander, Strauss, Mould and Parks. To Dr. Coleman Sellers, president and chief engineer of the Niagara Falls Power Company, and Mr. De Courcy May, late superintendent and engineer of the Cataract Construction Company, who, in consultation with Mr. Schmid and his assistants, made many valuable suggestions, the thanks of the Westinghouse Company are also due.

JOHN BOGART is one of the consulting engineers for the Cataract Construction Co., and, as such, has taken a prominent part in most of the work pertaining to the great Niagara enterprise.

THE MAIN STREET.

THE INDUSTRIAL VILLAGE OF ECHOTA AT NIAGARA.

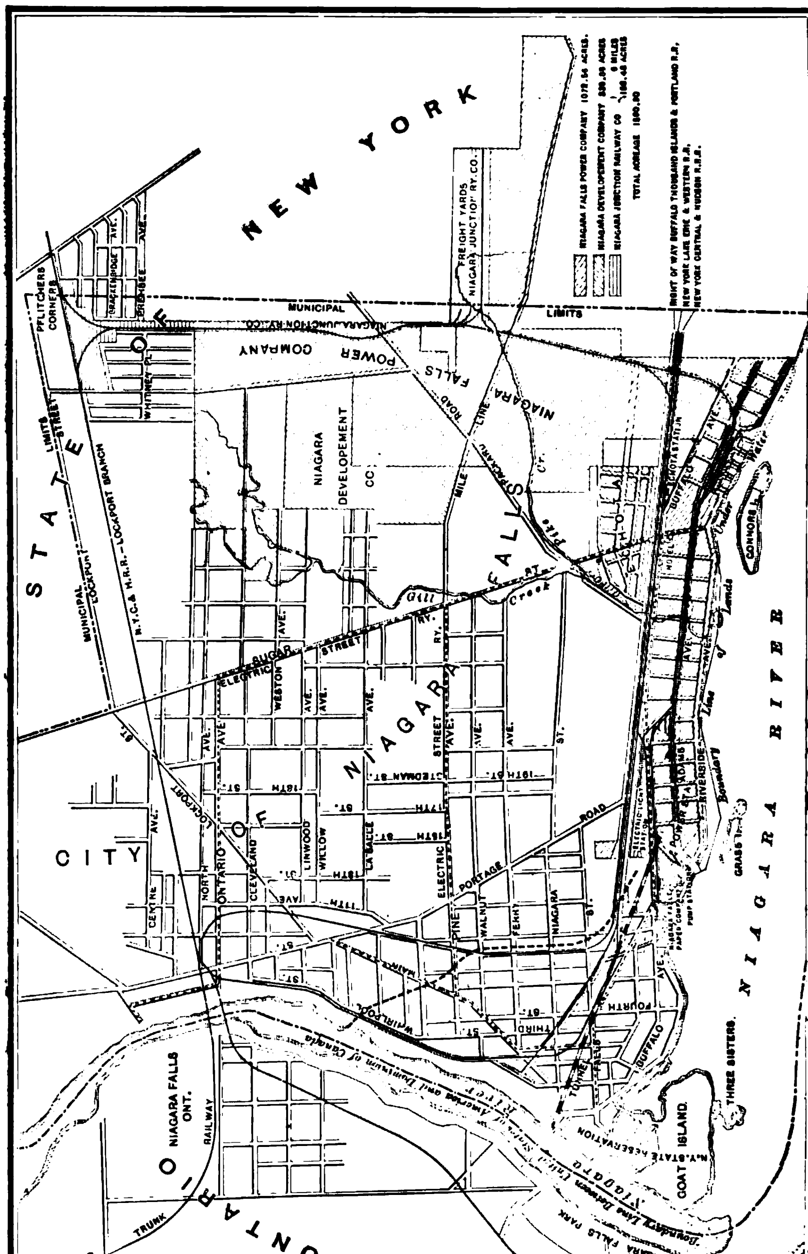
By John Bogart, M. Am. Soc. C. E.

THE lands of the Niagara Power Company extend about two and one-quarter miles along the right bank of the Niagara river. The enormous mechanical power there available, either by the direct use of water or by electrical transmission, will bring to these lands very large industrial establishments, some of which have been, in fact, already built, even before the power which they require could be furnished to them.

With such industries must come a large population of skilled labour operatives, mechanics, experts, foremen, clerks, accountants, superintendents and proprietors. It is in all respects desirable that the homes for these men and their families should not be too far from their work, and, therefore, the company owning the lands determined to create a residence neighbourhood which should have comfortable houses, with all practicable conveniences, with attractive surroundings, and which could be rented at very reasonable rates. A location was chosen near the centre of the lands of the company, and upon eighty-four acres, thus selected less than two years ago, there is now a very complete village.

The story of so speedy a development of an industrial village, a description of the plans adopted and of the methods of executing the constructions demanded by those plans should not be, under any circumstances, uninteresting. But in the case of this village of Echota, there were a number of special conditions which presented peculiar difficulties in determining the best solution of the various problems incident to a successful result.

The land upon which the improvements have been made is of oblong, but not exactly rectangular, shape, about 3000 feet long in a direction parallel with the Niagara river, and about 1500 feet in width. The river bank is distant about 1000 feet from the nearer line of the village. The whole area, both of the village and of the land between it and the river, is very flat, sloping very slightly to the bank. Over the whole eighty-four acres of meadow on which the village has now been laid out, there was an extreme variation of surface of four feet. The



LANDS OF THE NIAGARA POWER AND DEVELOPMENT COMPANIES.

general average level of the river, 562 feet above tidewater at New York, is about three feet lower than the lower parts of the village, but the water of the river occasionally rises to very nearly the elevation of this village surface. It was, therefore, impracticable to carry the drainage of these grounds to the river, with sufficient fall in pipes or gutters to quickly relieve the surface from the water of rainfalls, while to carry the requisite sub-drainage directly to the river was simply impossible.

The western boundary of the village is a stream of very moderate and sluggish flow in ordinary seasons, but suddenly expanding and overflowing with an enormous volume of water at times of heavy rainfall or sudden thaw. A branch of this stream, with the same characteristics, runs just north of the village line. The place is thus exposed on two sides to the overflow of these streams, and, in fact, the whole area of the village was covered with water of considerable depth soon after the beginning of the works of improvement.

Under a few inches of loam which covers these grounds, there is a stratum of about eight or nine feet of blue clay, then a red clay, and then a compact gravel and clay overlies the rock, which is found at depths of not less than fourteen feet. In their natural state these fields were in very bad condition for long periods after every rainfall, and during the gradual melting of the winter snow. The water gathered in shallow pools. There was not sufficient general surface slope to carry it away, and it could not pass through the tenacious underlying clay. It disappeared only by evaporation. Experimental excavations for cellars of houses retained water as tenaciously as well-cemented cisterns. The land during these seasons was wet, sticky and heavy, and when the water did evapo-

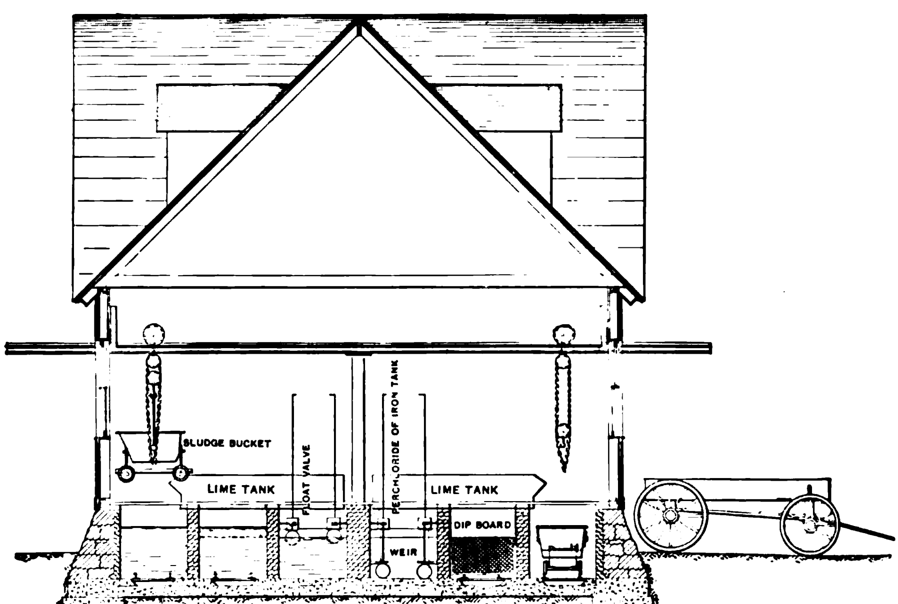
ANOTHER STREET VIEW IN ECHOTA.

THE SEWAGE DISPOSAL WORKS.

rate, the ground became baked and seamed with wide and narrow cracks in the hard clay soil. The roads in the vicinity were either very dusty or very muddy.

One of the features of the design is that every house shall be provided with a dry cellar and shall have a fair garden area. The plans for the streets also contemplate considerable grassy surfaces and ample provision of shade trees. It was, therefore, essential that the soil should be always in fit condition to maintain grass, lawns, trees, gardens and flowers.

Streets and roads cannot be kept in good order nor taken care of economically unless thoroughly under-drained.

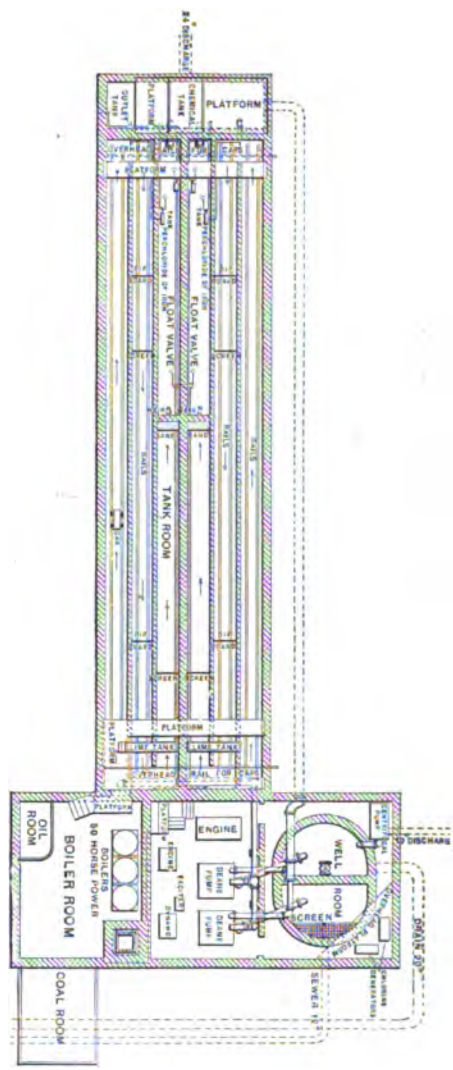


SECTION AND ELEVATION OF THE SEWAGE DISPOSAL BUILDING.

Furthermore, and of still greater moment, it would have been criminal to have invited families to take up their abode in houses built upon ground in such condition. Malaria and kindred diseases would have had a fertile field. But the waters, both of the small stream bounding the village, and of the Niagara river, some distance away, were at too great an elevation to receive even the rainfall running over the surface, to say nothing of the water taken from the subsoil deeply enough to give the free drainage required.

It was necessary also to provide an outlet for the sewage of the houses, and the elevation of the streams made a direct discharge into them impracticable. A discharge of this drainage and sewage into the lower river below the Falls, would have been possible, but it would have involved the construction of a conduit of great length, which, to secure the necessary gradient, would have been mostly in deep rock excavation and would have necessarily been of considerable size to provide, in addition, for the sewage of all the district lying between Echota and the lower river. The authorities of the city of Niagara Falls did not feel that it was necessary, at present, to extend their sewer system to Echota and the consulting engineer of the Niagara Development Company found a much less expensive method of providing fully for its needs. It will, however, be practicable to directly connect both the drainage and sewerage systems with the extended trunk lines of the city sewers when they reach Echota. The receiving well and the disposal house have been located particularly with this in view.

A complete system of under-drainage was designed and executed just as designed. The street plan of Echota, as shown in the illustration on page 313, includes alleys in the rear of the residence lots. Advantage was taken of this fact to separate the lines of drainage conduits, and those of the sewerage system, the latter carrying only house wastes. The principal pipes of the drainage system follow the streets; those to convey sewage are in the alleys. The latter are at a higher elevation than the drain tiles, and, thus, house connections for sewage can be made without danger of disturbance of the drainage system.



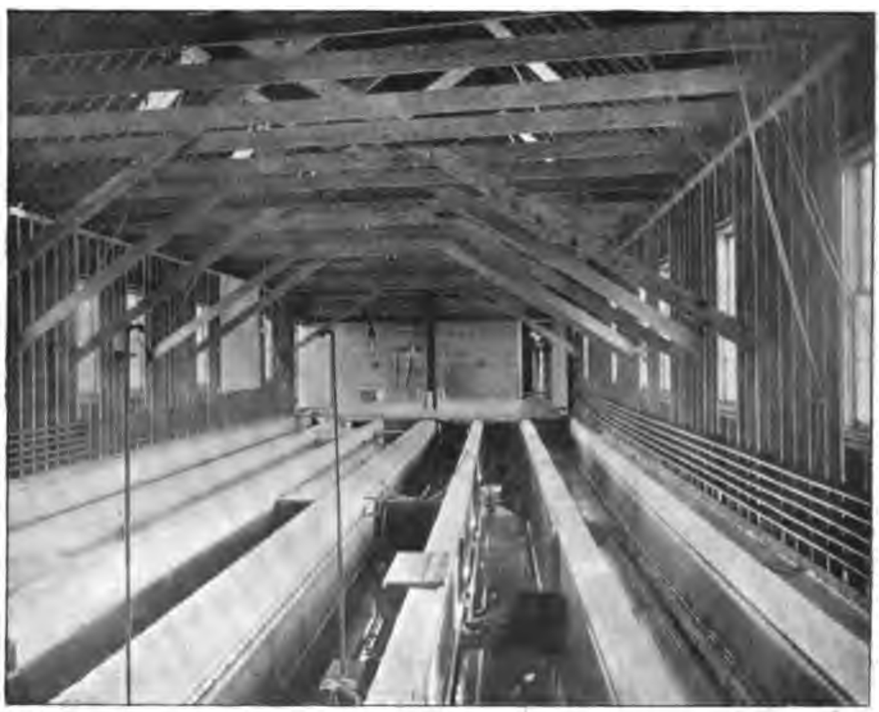
PLAN OF STATION FOR WELLS AND PUMPS, SEWAGE DISPOSAL AND ELECTRIC LIGHTING.

CROSS SECTION OF SEWAGE SETTLING TANKS.

The basis of the drainage plan is a

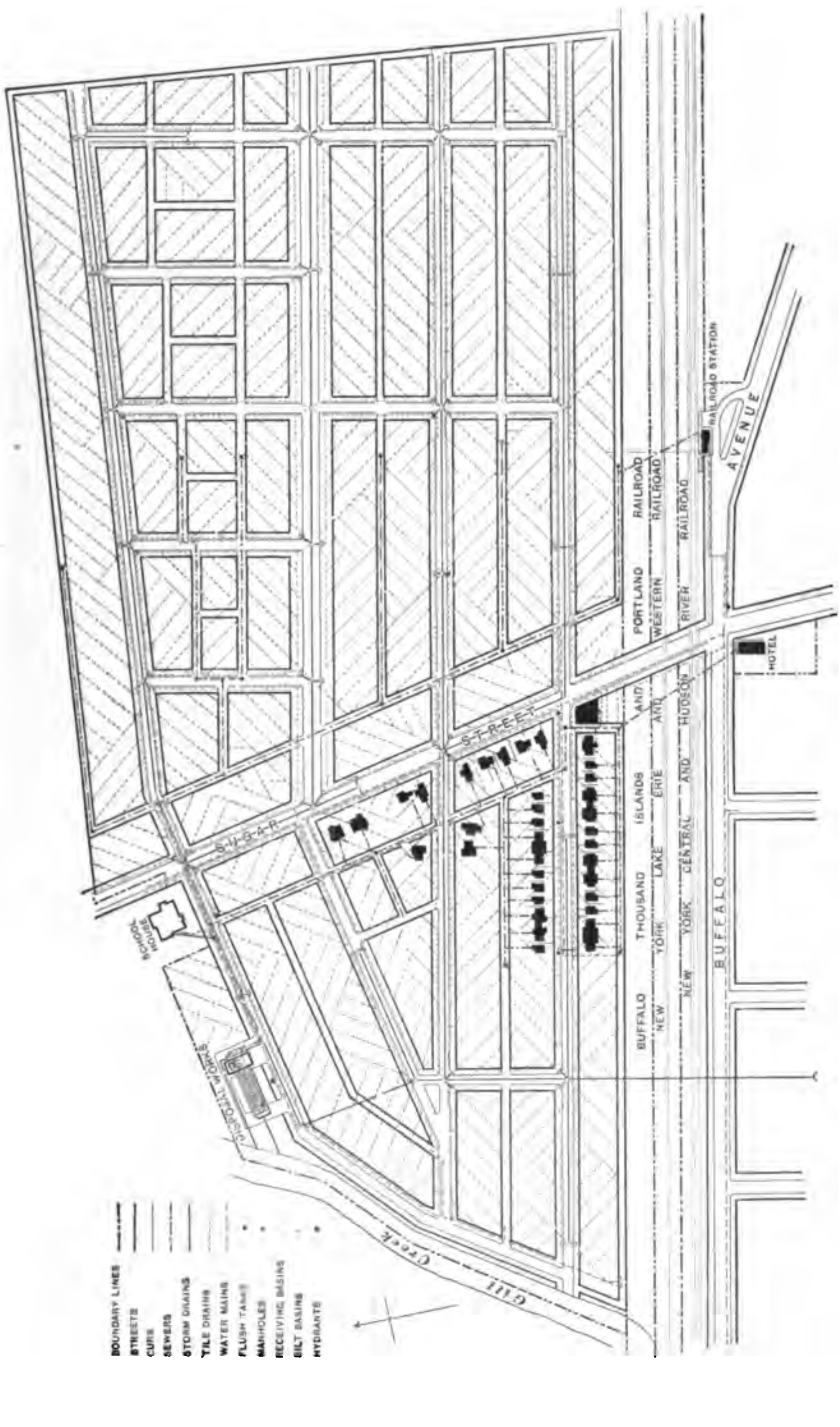
system of tiles of two inches internal diameter, and laid, as a rule, forty feet apart Their depth is, generally, from four to six feet below the surface. They have open joints, no cement or mortar being used, but around the joints was wrapped a double thickness of cheese cloth. Where strata of quicksand occasionally occurred, the tiles were laid on a board. The exterior of the tiles was octagonal. The minimum gradient was three-tenths of one per cent. and very great care was taken by the engineers in charge of construction to secure perfect alignment.

The excellent working of the system proves this to have been accomplished. The two-inch tiles deliver into lines of three-inch tiles, laid in the same way and placed, generally, in the streets, under the grass surfaces, but so disposed as to draw the water fully from the ground under and on both sides of the paved parts. All junctions of lines of tiles with other lines were made by special Y and T pieces, no cutting of tiles being allowed. The three-inch tiles led, at frequent intervals, to receiving basins in the centre of the streets, and the effluent from these basins is conducted by lines of vitrified pipe to a large masonry well, built near the northwestern angle of the village in connection with the sewage disposal works.

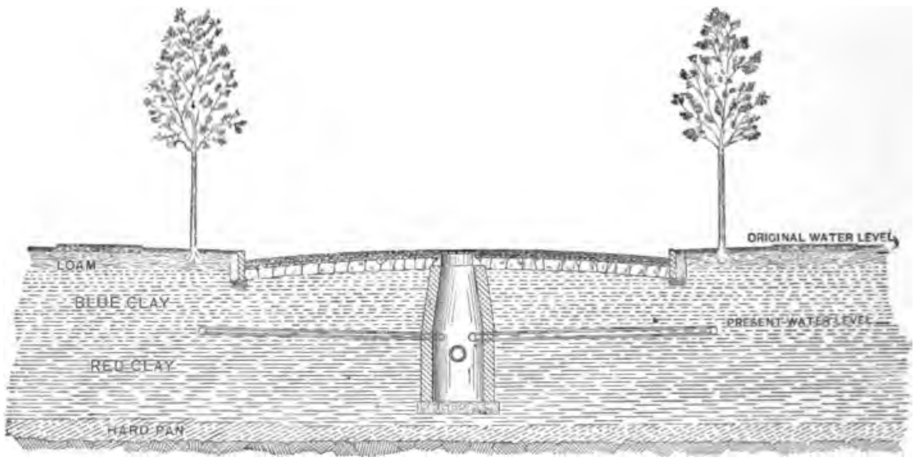


THE INTERIOR OF THE SEWAGE DISPOSAL WORKS.

This well is oval in form, 15 feet by 20 feet in diameter, and of sufficient depth to provide for the suction pipes leading to the pumps It is divided, by a brick wall, into two compartments, one of which receives the sewage and the other, the drainage water. The latter is pumped directly into the outlet chamber of the disposal works, whence it passes with the purified sewage effluent into the small stream above referred to and, thence, to the Niagara river. The illustration on the opposite page shows, by the fine dotted lines, that the



PLAN OF IMPROVEMENT OF LANDS OF THE NIAGARA DEVELOPMENT CO. AT ECHOTA.

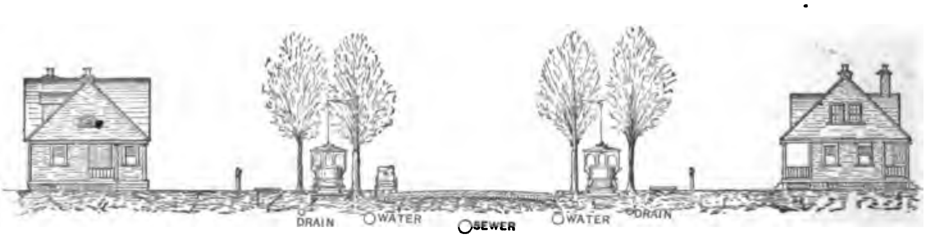


CROSS SECTION OF AN ECHOTA STREET WITH TELFORD-MACADAM PAVEMENT.

whole village is underlaid by this drainage system.

These open jointed small tiles have utterly changed the physical and sanitary conditions of the ground on which the village is built. It is no longer heavy or muddy after rains, neither is it dusty nor dry during the warm season. The hard clay has become friable ; the water of rains sinks quickly into the ground and disappears, grasses flourish, the lawns are in excellent condition, the trees which have been set out are healthy, and the cellars are perfectly dry. In fact, the level of the ground water has been lowered fully four feet, which is virtually, and for all horticultural and sanitary purposes, exactly the same as though the whole surface had been lifted four feet. The place no longer suggests dampness and discomfort, and the difference in the feel of the air is very perceptible to those who have spent much time there before and after the introduction of this drainage.

As every house to be built in the village is to be provided with running water, with closets and with kitchen sinks, a system of sewerage was required which would convey all house wastes quickly and certainly to their ultimate disposal. A separate system was designed, which takes no storm or drainage water. Its conduits are vitrified pipes, with a minimum interior diameter of six inches. These are laid generally in the alleys, at an elevation above the drain tiles. House connections will thus be made without disturbing the street surfaces. The pipes have cemented joints and are automatically flushed at regular periods. They conduct the sewage to one compartment of the well above described. From this well the sewage might be pumped to the small stream near at hand, or through a pipe of proper size, directly



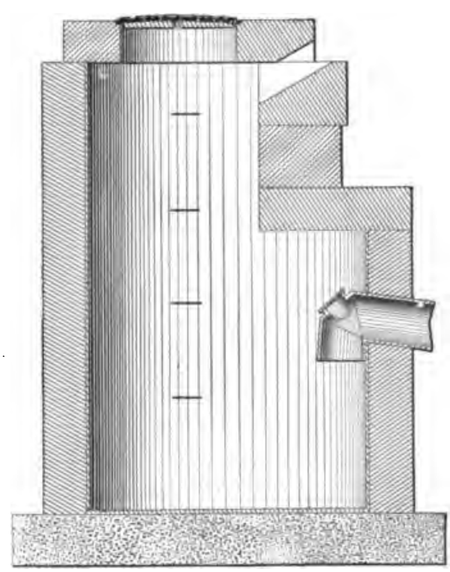
CROSS SECTION OF THE BOULEVARD AT ECHOTA.

into the Niagara river. While the dilution would be great, it was not deemed advisable, nor desirable, to thus deliver untreated sewage into the river, and a system was, therefore, adopted which secures the separation of all solids, the purification of the liquid and the delivery of an effluent deprived of all unsightly and unwholesome characteristics.

This is effected in the sewage disposal works of which the location is seen in the drawing. The details of construction of these works are also illustrated. There is a double set of elongated tanks or deposition chambers, so arranged in section and in length as to ensure a very slow passage of the sewage undergoing treatment. It is pumped from the well directly to the end of one of these elongated chambers, and is there treated automatically, by the action of float valves, with milk of lime and a solution of perchloride of iron.

Sedimentation and precipitation of the solids follow, and any floating substances are intercepted by screens. Chlorine is delivered through perforated pipes supported on brackets near the bottom of the chambers. When a certain quantity of the purified fluid has passed over a weir into the terminal tank, it flows, by syphonage, into the effluent chamber and, thence, with the pure drainage water, pumped from the other compartment of the well, it enters the stream. While one set of tanks is in use, the deposited material is removed by traveling buckets from the other tank, and is used upon the cultivated grounds of the company. The effluent is clear and clean. These works were constructed by Mr. James J. Powers, an expert in the treatment of sewage. The building which shelters the well, the pumps and the disposal tanks is of an exterior construction in harmony with the architecture of the dwellings in the village. This building has also the dynamo for the electric light service of the place.

The occasional sudden engorgement and overflow of the small streams at the site of Echota has been already spoken of. While the system of drainage will take care of all ordinary rainfall, experience on two occasions has given reason to feel that special measures were desirable to prevent the damage and discomfort which might follow the erratic action of these streams. At such times they overflow their banks. But observation has shown that a considerable expanse of country surrounding Echota may then also be under water. An elevation of the bank of



ONE OF THE CATCH BASINS FOR THE DRAINAGE SYSTEM.

the stream immediately adjacent to the village would not suffice.

In order to protect the whole area of the improved district, it must be guarded on every side. This has been accomplished by the construction of a bank or dyke along the boundary line and entirely surrounding the village. This dyke is eight feet wide on top, has side slopes of one and a half to one and is compactly built so as to resist the passage of water. On the east boundary of the grounds it is supplemented by a ditch on the outer side, ten feet in width, so placed as to intercept and carry to the Niagara river any volume of water that may come towards Echota

THE SCHOOL AT ECHOTA.

from the higher grounds above. Where the small stream above alluded to is adjacent to the village, the dyke is widened to fifty feet and becomes an exterior street.

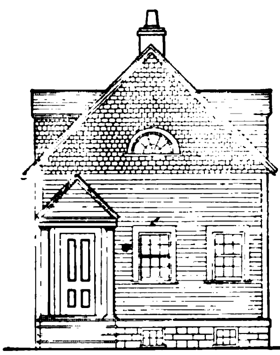
As an additional precaution, and especially to prevent any possible damage in the event of a temporary stoppage of the pumps, a relief conduit has been laid to the river, arranged with a check valve so as to open whenever the level of the ground water should rise higher than the water in the river. These combined measures have not only brought the land included within the boundaries of Echota to the satisfactory condition described above, but they have secured them from all danger of overflow.

The study of a design for the ground plan of streets was primarily affected by some existing conditions. The village was bounded on the west by the small stream, on the south by straight lines of railroad and on the north and east by defined property lines. There was one street, sixty-six feet wide, passing through the property, which could not, for legal reasons, be changed. Necessarily accepting these conditions, the plan adopted is shown on page 313.

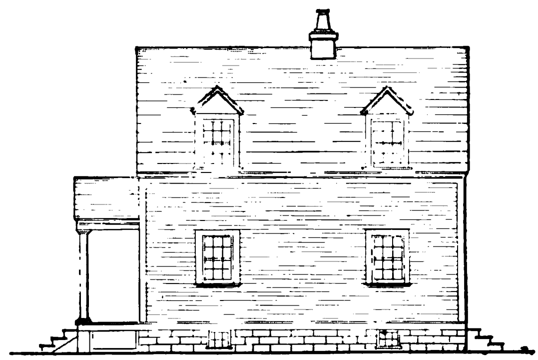
The system of streets and alleys was based mainly on parallelism with the longer side of the village. The streets are, generally, fifty feet in width, but all houses are placed twenty feet back from the street line. The fifty feet street thus becomes virtually ninety feet

wide, giving to each house a front yard and lawn. The lots are, generally, about 115 feet deep, some being still deeper and only a few being 100 feet. There is, thus, ample space for gardens and yards. A system including alleys was adopted after careful consultation with the officers of the company. Under the strict sanitary regulations which will be made and continued, the objections against alleys, found to exist in some places, will not there obtain. One street, to meet the extension of a proposed boulevard to Buffalo, is 100 feet in width. It has a roadway of forty feet, a provision for electric cars on each side of, and outside, the roadway, but near the curb and running between a double line of trees. The houses are to be, uniformly, twenty feet back from the street line, as is shown on page 314.

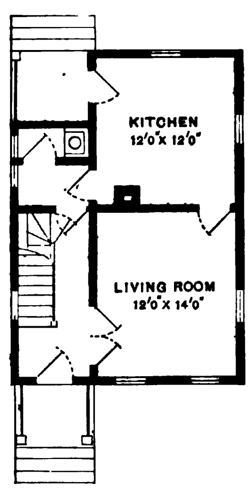
The streets of fifty feet in width have a roadway of twenty-five feet, and a single line of trees on each side. On the drawing of this street there are, incidentally, shown the lines of original water level and of the present level to which it has been lowered. The roadways have a Telford-Macadam pavement. This is formed by bringing the earth to lines parallel with the proposed



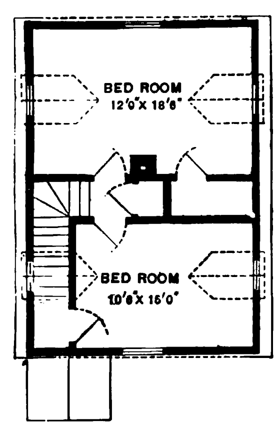
FRONT ELEVATION.



SIDE ELEVATION.



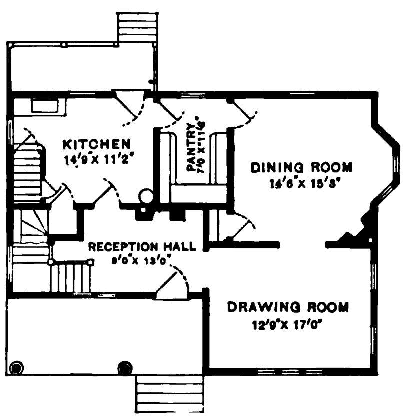
FIRST FLOOR.



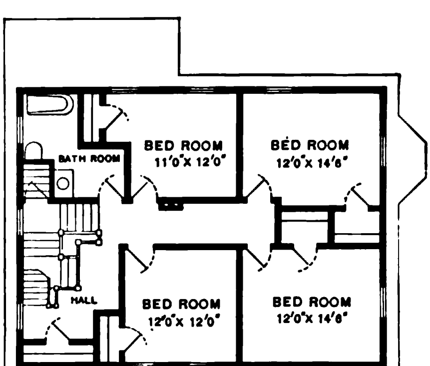
SECOND FLOOR.

ELEVATIONS AND PLANS OF ONE OF THE SMALL HOUSES AT ECHOTA.

FRONT ELEVATION.



FIRST FLOOR.



SECOND FLOOR.

ELEVATION AND PLANS OF ONE OF THE LARGER HOUSES AT ECHOTA.

final surface and the earth is then well compacted by rolling. On this surface is placed the Telford foundation of quarried limestone blocks, eight inches in thickness. Upon these stones is placed a small quantity of sandy binding material, and the surface is rolled smooth. Then follows trap rock broken into pieces not to exceed two inches in size. This is three inches in depth and, with another binding coat on its top, is again well rolled. There is then added another layer, two inches in depth, of trap rock, broken into pieces not to exceed one inch in size. This is rolled, covered with screenings from the broken trap and finally brought to the required lines by thorough rolling, using water during the operation. A steam roller is used for this work.

Maple and elm trees have been set three feet within the lines of curb. The paved surfaces have a crown of four inches in the width of twenty-five feet, and of six inches on the one street, Sugar street, where the pavement is forty-two feet in width. The grades of streets and gutters are necessarily very light, but the lines have been laid so truly that no trouble has been experienced from stoppage of the flow of water. Inlet basins, of which the construction is shown by the sketch on page 315 are placed at the corners of streets and at other points, so that they are never farther apart than 440 feet and generally not more than 300 feet. These receive the water from the street surfaces and gutters and are connected by trapped inlets with the drainage conduits. They have a large depressed chamber below the level of the outlet pipe, in which any solids or street detritus are precipitated by gravity and frequently removed through the cover at the surface.

The same provision of a settling or silt basin, to intercept detritus, is made in the basins receiving drainage from the lines of sub-surface tiles, and wherever more than two lines of tiles met at one point there was placed a silt basin, made of vitrified pipes, fifteen inches in diameter, extending below the inlet and outlet. Connections with

these basins were made by special vitrified pipe with branches to fit the angles of the drains.

All the houses in the village are built by the company. Their architecture combines a general uniformity of design with much variety in form and detail. The architects were Messrs. McKim, Meade & White, of New York. The general appearance of the houses is well indicated in the several illustrations reproduced from photographs. All are painted in the colors adopted by the company,—yellow and white.

ASSEMBLY ROOM, STORE AND HOUSES AT ECHOTA.

Houses for about fifty families have already been built. These vary both in exterior appearance and interior arrangement. One of the simpler and smaller houses and one of the larger and more elaborate ones are illustrated by elevations and plans on pages 317 and 318. The smaller house has four rooms of good size and also a large cellar. It has electric light, running water, closet and kitchen sink. Some of the houses with this ground plan and number of rooms are detached, others are built with either two or four under one roof, but with entirely separate entrances in the front and rear, and each with its own yard and garden space. The larger house has ten rooms, with furnace, bath and other desirable arrangements. The rental for the houses runs from $9 to $30 (£1 16s. to £6) a month and includes, in each case, water and electric light. It is the intention of the company, as soon as the character of the settlement is firmly established, to give its tenants an opportunity to purchase their homes on easy terms, thus avoiding the evils which have at times resulted from the too positive application of the proprietary system. The general appearance of the parts of the village where houses have been built is very pleasing and attractive.

Water, filtered by the Morison & Jewell gravity system, is furnished by the Niagara Falls Water Works Company, one of the allied companies of the power company, and hydrants are placed at convenient distances. Ample provision of hose is made for fire protection. The streets are lighted by incandescent lights of fifty candle power

LOOKING DOWN ONE OF THE STREETS AT ECHOTA.

each. A large building has been placed at one of the prominent street corners. The lower floor is for a general store, and the upper floor has a handsome hall, with dressing and toilet rooms, which is put at the service of the residents of the village. A commodious brick school-house, also, has recently been built at Echota by the city of Niagara Falls.

All the works of construction have been continuously in charge of the resident engineer, Mr. W. A. Brackenridge, who has also given many valuable original suggestions, particularly in the development of the protection dykes, the construction of the roads and the arrangement of the houses. The word Echota signifies, in the Indian language, "Place of Refuge." It was suggested as an appropriate name by Mr. Edward D. Adams, the president of the Cataract Construction Company.

Echota is adjacent to the principal lines of railroad, the company having already built a handsome station on the New York Central and Hudson River Railroad. Two principal streets of the city of Niagara Falls run past and through the village, and lines of electric cars are now in operation, connecting with all parts of the city. At the foot of one of the main streets of the village is the wharf from which a daily line of steamers runs to Buffalo.

The village of Echota has, thus, been evolved in accordance with the careful study of the men to whom was committed the responsibility of the solution of a complex problem. A district, not fit for comfortable residence, has been transformed into an ideal, healthful village. Ground upon which no vegetation would thrive has been changed to a region of velvet lawns and blooming gardens. Roads which were a discomfort from dust, or an annoyance from mud, have been made into well-paved, beautiful streets. An unattractive expanse of poor meadowland has become a model town, with inviting residences at very moderate expense for the families of all who may have to do with the busy industries called into action by the wonderful power drawn from the Falls. The prudent foresight of the managers of capital, the artistic design of the architects and the well-matured plans of the engineers have given a result about which the author does not hesitate to write, because that result will have an effective part in the great story of the successful development of the forces of Niagara.

NOTABLE EUROPEAN WATER POWER INSTALLATIONS.

By Col. Th. Turrettini.

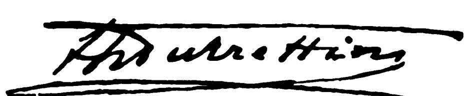
HAVING been invited by the editor to contribute, as consulting engineer to the Cataract Construction Company, an article to this number of CASSIER'S MAGAZINE, it seems proper to say that my English and American colleagues, who are living closer to the great Niagara work, are better able than I to speak of this gigantic undertaking, and to describe how the impetuous Niagara river was mastered and how the wonderful machinery was installed, which, by electric means, will spread light and power far around Niagara Falls.

Leaving, therefore, all account of the Niagara plant to others, I will endeavour to give, for interesting comparison, a description of similar works which have been, or are being, carried out in Europe, more especially the works which the city of Geneva, in Switzerland, is now building and which I have the honour of directing as president of the Geneva municipality and director of its public works.

In comparison with the installation at Niagara Falls even the greatest European works for the utilization of water power are small ; they are to the Niagara works in the proportion of the European to the American continent, in the proportion of the Rhône or the Rhine to the Mississippi and the St. Lawrence.

The town of Schaffhausen, on the Rhine, was the first in Switzerland to endeavour to use the river passing through it to procure power for driving the machinery of the manufacturers in its neighbourhood. Its works were established twenty-one years ago through the generosity of one of its wealthy citizens, M. Moser, who, to endow his native city with this important water power, laid out large sums of money. At that time no other means of transmitting power was known than that of wire ropes, and to that purpose very costly apparatus was set up in the middle of the river, the Rhine being dammed up so as to procure a fall to drive a set of turbines. About 1500 horse-power was obtained in this way and was distributed to neighbouring workshops. The system of wire ropes necessarily limited the development of the works, and the Schaffhausen plant remained as it was when started, until the progress of electrical knowledge allowed of further extension. Three years ago, three new turbines, of 500 horse-power each, were added, driving dynamos which distribute electric power to neighbouring factories.

The example of Schaffhausen was followed a few years later at Bellegarde, on the Rhône. The little town of Bellegarde is situated in France close to the Swiss frontier. There the Rhône, cased in between high cliffs of rock, has pierced for itself a subterranean channel in which it disappears entirely in winter when the waters are low ; for this reason the place is called the "Perte du Rhône." An English company obtained the concession to establish in this place a water-power plant amounting to several thousand horse-power. The company formed a reservoir to receive the waters of the Rhône above the "Perte du Rhône," cut a tunnel in the rock about 1200 meters, or nearly 4000 feet long, and erected a



COL. THEODORE TURRETTINI was one of the members of the International Niagara Falls Commission. He is now president of the municipality of Geneva, Switzerland, and director of its public works.

building for the housing of six turbines of 630 horse-power each, working under a head of water of 14 meters, or about 46 feet. The water-power was used to pump water to the upper level of the town above, and to distribute power in Bellegarde by means of the previously mentioned wire ropes. There, again, the cable transmission was a cause of restraint in the development of the works and several companies succeeded one another without attaining the utilization of all the available power.

In 1878, the town of Zurich established in the Limmat, where it issues from the lake, and in the town itself, works of 1500 horse-power, by the successive setting up of several turbines of 200 horse-power, working under a fall of water varying between 2 and 3 meters, or about 6½ and 10 feet. These remarkable works were constructed under the direction of M. Burkli, then town-engineer of Zurich. The greater part of the power obtained was used for providing water to the town; what remained was distributed to factories for driving small private turbines up to 5 horse-power. Besides this, from about 200 to 400 horse-power could be distributed by wire rope to an industrial quarter in the immediate neighbourhood of the water-works. While the distribution of power through water-pressure was rapidly taken up, the distribution of power through cables proved a failure just as it had been at Schaffhausen and Bellegarde.

At the same time a company was formed in Fribourg, for utilizing the power of the Sarine in the immediate neighbourhood of the town of Fribourg. There were 1500 horse-power to be disposed of, and the system of transmission was again that of wire rope. The use of this system of transmission was there again a failure, and the company had to be wound up. Several years ago the works were bought up by the Fribourg Government, and electric transmission was introduced. This transformation has given the works a fresh start and they are now doing well.

In 1882, I was elected by my fellow-citizens to the direction of the public works of the town of Geneva in consequence of a paper which I published in support of the idea of utilizing the whole power of the Rhône as it issues from the lake of Geneva and passes through the town. The studies made with that object, and to which several distinguished Swiss engineers contributed, such as Messrs. Merle d'Aubigné, Legler, A. Achard and Prof. Pestalozzi, proved that the Rhône afforded, at Geneva, about 6000 horse-power. The system to be adopted for the distribution of the power was the subject of a special study.

Wire rope transmission of power had been condemned by experience, for it has been amply proved that factories will not come to the source of power, but, on the contrary, that the power must be transmitted to wherever factories are established. Transmission by compressed air gave unsatisfactory results, and transmission by electricity had not, in 1882, reached the degree of perfection which it has attained since then, and could not be thought of.

The only system which remained to be considered was that of water under pressure, and this was the means of transmission which was adopted. Experience has proved that the choice of that system was a good one. The efficiency of water-pressure transmission is not considerable, but this drawback was counterbalanced by numerous advantages, some of which result, it is true, from the special situation of Geneva. The water of the lake, employed for the distribution of the power, is absolutely pure. It could, therefore, be utilized as drinking water, as well as for general industrial purposes and motive power. The same water mains could also be used for town uses and for working private turbines. The water employed, containing no sand in suspension, does not wear out machinery.

The studies preliminary to undertaking the new works were completed at the end of 1883. A credit of two million francs was voted by the Municipal Council of Geneva and the works were begun at once. The plan consisted in

THE 6000 HORSE-POWER STATION AT GENEVA, SWITZERLAND, COMPLETED IN 1886.

THE NEW POWER HOUSE NEAR GENEVA, CONTAINING 15 TURBINES OF 1200 HORSE-POWER EACH.

the setting up of eighteen turbines, of 300 horse-power each, representing a total of 5400 horse-power. The available fall varied between 1.80 meter (about 6 feet) in summer, and 4 meters (about 13 feet) in winter.

The first credit which was voted contemplated the carrying out of all the construction work, dams, buildings, etc., and the establishment of five groups of turbines and pumps. The regulation of the level of the Lake of Geneva formed a part of the new scheme. For more than 200 years constant quarrels had arisen between the inhabitants of the lake shores and the city of Geneva because of a supposed raising of the level of the lake arising from the works carried out in the Geneva estuary, and it was hoped that the carrying out of the new scheme for utilizing the forces of the Rhône would allow an end to be put to these disputes. Geneva obtained 1,100,000 francs from the various States bordering on the lake to carry out, simultaneously with its water-works, a movable dam which would permit keeping the lake always at exactly the same level in all seasons.

The works were actively pushed along and on June 16, 1886, the inauguration festivities took place. Thanks to the system of power distribution adopted, the development was faster than had been anticipated, and to-day, in less than nine years from the starting of the machinery, seventeen turbines, out of the eighteen contemplated, have been erected and the eighteenth is now being constructed. From a financial point of view, the town of Geneva has done well, for, in the year 1894, the works gave a net profit of 2½ per cent. after deducting 3½ per cent. for the interest on the capital and the sinking fund for the wear and tear of machinery.

The capital engaged in this undertaking amounted, on December 31, 1894, to 5,500,000 francs. This comprised the cost of the system of water pipes for distribution which, put end to end, would be 140 kilometers, or about 87 miles long.

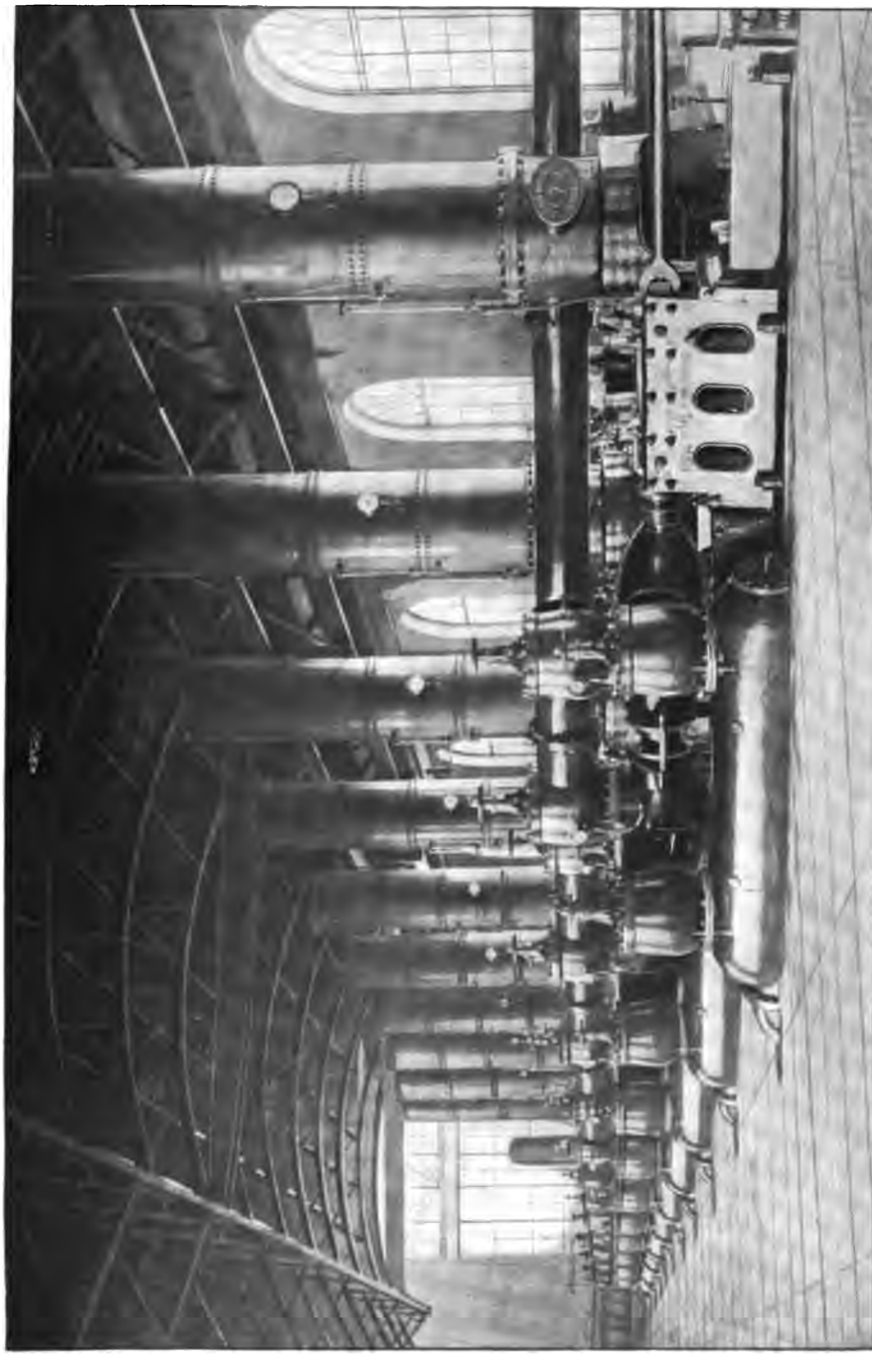
The success of Geneva in the establishment of water motive power encouraged other towns also to try to make use of the natural water power in their neighbourhood. At Lyons, in France, a company was formed to construct a diverting canal above the city and create a fall of about 8 meters (about 26 feet) at a place called Jonage, about

5 kilometers (3 miles) from the city. About 15,000 horse-power is available there and electrical transmission will be employed. The works have just been commenced.

At Rheinfelden on the Rhine, about 15 miles above Basle a company has obtained a concession for 12,000 horse-power, under 4 meters (about 13 feet) fall. The works are to be commenced at once. In the canton of Neuchâtel, the river Reuss, which comes down the Val de Travers, is going to be completely utilized in four successive plants, each to develop 1000 horse-power. This power will supply the wants of the towns of Neuchâtel, Chaux de Fonds and Locle, and also of all the Val de Travers. In the canton of Soleure 3000 horse-power will be obtained in a short time from the river Aar above Soleure and will supply that town and its neighbourhood. On the same river, at Viznau, near Langenthal, the firm of Siemens & Halske is constructing works to obtain about 2000 horse-power and to distribute it in the neighbourhood.

Examples of similar undertakings could be multiplied. The town of Geneva, encouraged by the success of its first venture, decided in 1892 to establish on the Rhône, about 6 kilometers (nearly 4 miles) down stream, new works, very much more powerful than those previously built. A short description of the locality will render the adopted plans clearer. The first works, mentioned above, were situated in the town itself. But, at a point 1500 meters (5000 feet) below the town, the clear blue Rhône receives the river Arve which descends from Mont Blanc. The waters of this river, coming direct from the glacier, are as troubled as those of the Rhône are limpid. Beyond the junction of the two rivers, their waters run side by side, without mixing, for about a kilometer (0.6 mile), forming a blue and a white riband. Thanks to Geneva Lake, the Rhône has a flow of water varying from 120 to 700 cubic meters (4230 to 24,675 cubic feet) per second, whereas the flow of the Arve varies from 20 to 1200 cubic meters (700 to 42,300 cubic feet) per second. Below the junction of the two rivers, the Rhône runs deeply cased in between wild cliffs for several miles, and this has allowed the adoption of a very simple plan for the establishment of the new works.

THE STONEY DAM NEAR GENEVA, BUILT IN 1895.



THE INTERIOR OF THE 6000 HORSE-POWER STATION AT GENEVA.

The place selected for setting up the dam and the buildings for the turbines, called Chèvres, is about 6 kilometers (nearly 4 miles) below the former works. The width of the river, after the erection of the works, will be 130 meters, or about 426 feet. On the left bank, a Stoney movable dam, the same as that adopted for the Manchester canal, in England, allows the raising of the level of the river. The dam, which is 90 meters (295 feet) long, is connected with the right bank by the building containing the turbines. This building is placed in a skew position along the supply channel, and, in connection with the Stoney dam, forms a complete dam across the river.

The dam has six openings, each 10 meters (about 33 feet) wide. Each opening can be closed ad libitum by a sluice, 8 meters (about 26 feet) high. The sluices are in one piece, hung with counterweights, and slide on rollers. Thanks to this, they are easily lifted or let down by two men, in spite of the enormous pressure of water which they bear. The fall produced by the dam varies with the seasons. It is 8 meters, or about 26 feet, high in winter, and diminishes to 4.50 meters, or about 15 feet, in summer.

The building for the turbines is 150 meters (492 feet) long and will eventually contain 15 turbines of 1200 horse-power each. To obtain a sufficient velocity for directly working the dynamos which they set in motion, each turbine is composed really of two turbines of 600 horse-power, placed one above the other on the same shaft. In winter, when the fall is highest, the lower turbine alone is open ; in summer, when the fall is less, the two turbines work simultaneously. The wheels were constructed by the Messrs. Escher, Wyss & Co., of Zurich.

The dynamos, constructed by the Compagnie de l'Industrie Electrique de Genève, are on the two-phase system. Each turbine-shaft carries two dynamos of 600 horse power. The teeth of one of the wheels are displaced by a quarter of the pitch with respect to those of the other wheel and each has a separate exciting current so as to be able to vary the load of each machine without inconvenience. The weight of each dynamo is about 70,000 kilog., or about 154,000 lbs.

The armature is fixed, and the revolving part, weighing 16,000 kilogs., or about 35,200 lbs., contains no wire and is only a mass of revolving steel. The speed of rotation is 80 revolutions per minute. All the dynamos may be coupled in parallel. The aerial transmission, 6 kilometers, about 3¾ miles, long, mounted on iron posts, is composed of return wires concentric with the outgoing wires, so as to reduce induction as much as possible. The transmission for light will be independent of the power transmission. The tension is 2400 volts.

These new works of the town of Geneva, which will make another 18,000 horse-power available, are nearly completed. The first three turbines are being erected and the dynamos are ready, so that the machines will be started during this summer. The works have been carried out under my direction by M. Butticaz, chief engineer of the Geneva water and water-power works. They will be the most important in existence after those at Niagara Falls, but they are very far from rivalling them. My purpose in writing these lines has been to furnish a point of comparison which would allow one to gauge the immense advantages of the gigantic instrument which American industry now possesses.

S. Dana Greene

S. Dana Greene is a U. S. Naval Academy graduate, and resigned from the Navy in 1887 to become assistant, and later, chief engineer of one of the prominent electric establishments. He is now assistant general manager of the General Electric Company.

WINTER AT THE FALLS.

DISTRIBUTION OF THE ELECTRICAL ENERGY FROM NIAGARA FALLS.

By S. Dana Greene, Electrical Engineer.

THE utilization of at least a portion of the enormous amount of energy which, in the parlance of this practical age, "runs to waste" annually over the Falls of Niagara, has been written and talked of, studied and suggested, for the past hundred years. It has been reserved, however, for those of us who will see the nineteenth century rounded out and the twentieth ushered in, to witness the practical accomplishment of this great undertaking.

Other articles in this magazine tell of the engineering skill, perseverance and ingenuity which, combined, have helped to bring about the harnessing of Niagara. It is the purpose of this article to point out some of the applications to which the electric energy generated at the Falls has already been put, and to discuss other applications which suggest themselves as probabilities or possibilities. These applications can be broadly divided into two classes: (1) Those which are undertaken near the generating station, within a radius of, say, ten miles. (2) Those which necessitate a transmission of the power for a distance of more than ten miles before it is utilized.

The first class offers a tempting field to those practical men who prefer present certainties to future possibilities; while the second class presents an array of scientific problems, and of theoretical and empirical studies and calculations which are attracting the attention of the whole engineering world. Time alone can tell how many of these problems will be solved, and how far practical results will verify the theoretical figures. We may, however, assume with reasonable certainty, that as the science of electricity, which is yet young, advances from year to year, the area of

THE ELECTRIC PLANT OF THE PITTSBURGH REDUCTION COMPANY AT NIAGARA.

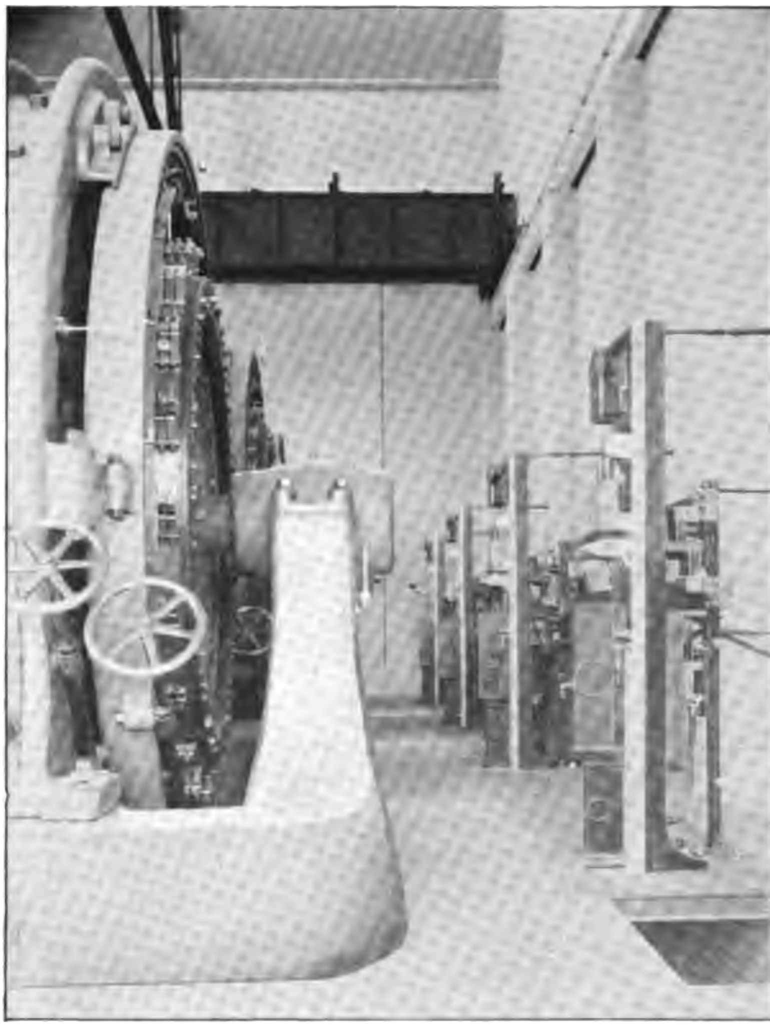
influence of the Niagara power will be constantly extended, until that historic and picturesque spot becomes a true electrical Mecca. When this result shall have been accomplished, the far-seeing business sagacity and engineering talent of those who have launched the present enterprise will bear their fruit, while the capitalists who have boldly invested their millions will have their proper reward in a handsome and ever-increasing return on their investment.

Before discussing in detail the two classes of application already mentioned, it is well to glance at some of the broader questions involved. The electric motor is already well-known as a piece of commercial apparatus. Thousands of them are in daily use, having displaced steam and gas engines and other forms of power motors. It is compact, easily cared for, very reliable, and, with a continuous rotary motion, it can be applied to its work with a minimum of expense and complication. For reliability, simplicity and certainty of operation, it stands without a peer in the motor field. It follows, as a matter of business, that industrial power consumers can, with profit, substitute the electric motor for that which they now use, provided the electric power can be delivered to the motor at a cost less than that now paid for other power, including the cost of operating and maintaining the motor.

Such a change of motive power has been, as a matter of fact, progressing actively for the past five years, especially in the larger cities, where a network of wires, either overhead or underground, has gradually covered the territory like a system of gas or water pipes, ready to be tapped for any consumer who desires to use the electric power. The extent to which the change has been effected is not generally realized. Thus in New York, it is estimated that not less than 8000 horse-power in electric motors are at present in use, the motors varying in size from 1/8 horse-power to 100 horse-power; in Brooklyn about 4000 horse-power are employed, while 25,000 horse-power additional in motors are used in that city for electric traction purposes.

In many large industrial manufacturing establishments it has been found economical to generate electric power in a central power station, and then distribute it throughout the various shops, electric motors being utilized to operate the lines of shafting, heavy tools, cranes, rolling mills, etc. In all of these applications, the reason for the change in power is found, first, in the ease and economy with which the elec-

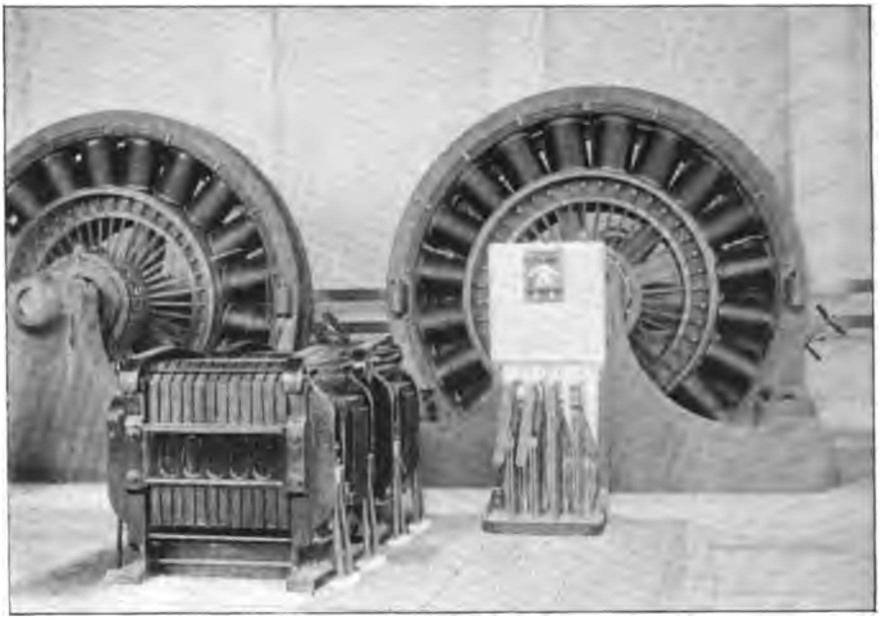
tric power can be transmitted; and, second, in the high efficiency and low cost of maintenance of the electric motor. Although additional conversions of energy are involved, these conversions are accomplished in large units,



DIRECT-CURRENT SIDE OF THE ROTARY CONVERTERS AND THE LOW-TENSION SWITCHBOARDS.

under the most economical conditions, so that there is an actual and very important saving to an establishment using electric power throughout, instead of steam, or compressed air, or rope transmission.

In addition, electricity has a large, and ever widening field in lighting, heating and cooking; in plating and electrotyping; in the smelting and reduction of refractory ores; and in surgical and medical work. It is, in fact, becoming more and more a part and parcel of our every-day practical requirements, while in the language of the patent office, "new and useful" applications are in daily process of invention and development.



TWO OF THE ROTARY CONVERTERS AND ALSO TWO OF THE STATIC TRANSFORMERS IN THE PITTSBURGH REDUCTION COMPANY'S PLANT.

With such a field of usefulness for electric power, and with the assurance of the best technical advice attainable that the work was feasible from an engineering standpoint, and that the cost was not at all prohibitive, one can realize why it has been possible to secure capital for the Niagara power plant; and as the present power house stands ready to deliver fifteen thousand horse-power in electrical energy, with an ultimate capacity of fifty thousand horse-power (the intake canal being large enough to supply two power houses of this capacity), we can consider the near-by applications of power about to be made.

The Niagara Falls Power Company owns somewhat more than a square mile of land around the power house, and it purposes to rent or sell this land to industrial establishments desiring to locate there, and to sell them electrical power, available for twenty-four hours a day, every day in the year, at a price so low that these establishments can afford to move from their present locations and sell their present plants.

The power, as generated, is an alternating two-phase current of twenty-five cycles per second, or three thousand alternations per minute, the electromotive force, or electrical pressure, being about two thousand volts. At this voltage, and with the short distances involved in local distribution, the transmission involves no engineering difficulties, electrical or otherwise; in fact, it is similar to many such transmissions in various cities and towns. Many inquiries have been received from all parts of the country asking for information as to the character and cost of the power service, the amount of power available, etc.

Two manufacturing establishments have already closed contracts, erected new plants on the ground, and are about ready to start operations, viz.: the Pittsburgh Reduction Company, of Pittsburgh, manufacturers of aluminium, requiring 2000 horse-power; and the Carborundum Company, also of Pittsburgh, manufacturers of carborundum, a variety of emery, requiring 1000 horse-power. As each of these companies will utilize

the electric current for a special purpose, each differing entirely from the other, a brief description of the two plants will be of interest.

The Pittsburgh Reduction Company produces pure aluminium,—a metal which is beginning to attract favourable attention—from alumina, an oxide of aluminium, by smelting the latter with the proper flux, in carbon-lined retorts or crucibles, the mass being liquefied and the aluminium reduced by an electric current, passing from a series of carbon rods suspended over the top of the crucible and forming one pole of the circuit, to the carbon lining at the bottom of the crucible which forms the other pole. The current required is what is commonly called a direct current, the voltage, or pressure, at the terminals in the reducing room being maintained constant at 160 volts, and about 60 retorts being placed around the room in series with one another.

As the current, delivered to the Pittsburgh Reduction Company by the power company, is of the two-phase variety, alternating, at 2000 volts pressure, it is necessary to reduce this pressure and then transform the current from alternating to direct. The first change is accomplished by passing the current through large "static transformers," built on the principle of the Rhumkorff coil, by which the voltage is reduced from 2000 to 115. The current is then passed through a "rotary converter," where it is changed from a two-phase alternating current at 115 volts to a direct, or continuous, current at 160 volts. The rotary converter is a direct-current generator, with the addition of proper collecting rings and connections on the rear of the armature, by which the alternating current is led into the machine. It may be considered, in fact, as a motor and generator in one machine. The illustrations on pages 334 to 337 show the power room of the Pittsburgh Reduction Company's plant, with the apparatus installed and ready to operate. The plant has a capacity, on the direct-current side, of 10,000 ampères at 160

THE ALTERNATING CURRENT SIDE OF THE ROTARY CONVERTERS, THE ALTERNATING CURRENT SWITCHBOARDS AND THE STATIC TRANSFORMERS.

ONE THOUSAND HORSE-POWER STATIC TRANSFORMER AT THE WORKS OF THE CARBORUNDUM COMPANY. BUILT BY THE GENERAL ELECTRIC CO. NEW YORK.

volts, or 1600 kilowatts,* or about 2000 electrical horse-power.

The Carborundum Company utilizes electricity in a different way. A large core of carbon, about 8 feet high and a square foot in cross section, is placed vertically in a large smelting furnace, and around this core is packed the carborundum ore. An alternating electric current is then passed through the core from end to end, the core being gradually brought to an intense (white) heat. This heat is kept up for about twelve hours, the carborundum being gradually reduced from the ore, in crystalline form.

The crystals are taken from the furnace, ground to a powder and pressed and moulded in various forms for use as emery. The Carborundum plant

* A kilowatt (one thousand watts) is the electrical unit of power. An electrical horse-power, 746 watts, is about ¾ of a kilowatt.

consists of a 1000 horse-power static transformer, by which the voltage is reduced from 2000 to 100 and 200 volts, and a special regulator of about the same size, by which the voltage at the core of the furnace is varied as the resistance of the core changes, owing to its change of temperature, the current being maintained about constant. The illustrations on pages 338 to 341 and on page 348, show this apparatus in completed form. The Carborundum plant is unique, both on account of the way in which the electric power is utilized and also on account of the size of the static transformer and regulator, which are the largest pieces of apparatus of the kind ever built.

Static transformers of the size used in these two installations (270 horse-power and 1000 horse-power respectively) require some artificial method of cooling, for, notwithstanding the fact that the transformers have an efficiency of from 97 to 98 per cent., the energy transformed into heat is, nevertheless, so great that there is not sufficient radiating surface to carry it off, and the temperature at full load would soon rise to such a point as to endanger, if not destroy, the apparatus. Two different plans of cooling have been adopted. In the Pittsburgh reduction transformers a blast of air is forced constantly through the numerous interstices between the coils, from below, and the heat is thus easily controlled.

The Carborundum transformer is cooled by a continuous circulation of oil. The transformer is placed in a cylindrical iron case, standing on a ring about 6 inches high from the bottom of the case. Oil is forced into the transformer from the bottom, and up through its interstices, until it flows over the top and into the surrounding case. It is then drawn off, passed through a cooling coil surrounded by running water and is again forced through the transformer. The resulting decrease in the temperature rise is the same as in the case of the air blast. In either case the amount of power required for the air blast or for the oil circulation is very small—less than ½ per cent. of the capacity of the transformer.

Another application about to be made of the power is the operation of the electric road at Niagara Falls, and also of that now being pushed to completion, as a rapid transit line, between Buffalo and the Falls. About 1500

ANOTHER VIEW OF THE STATIC TRANSFORMER.

horse-power in rotary converters will be required for this work, in 500 horse-power units, transforming the alternating into direct or continuous current at 500 volts. The electric lighting station and the water works at the Falls will probably also utilize the power at an early date.

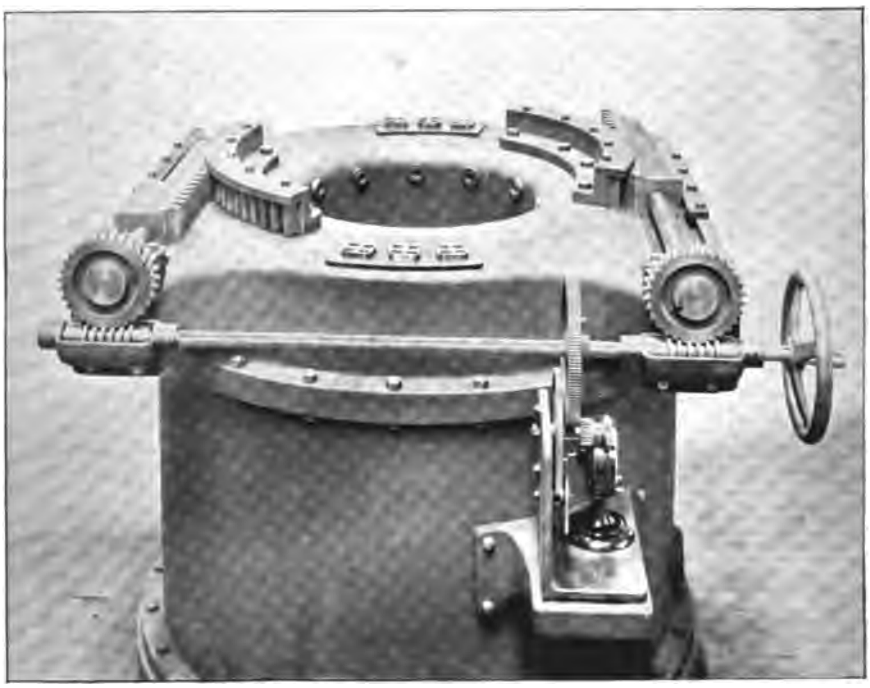
With nearly 5000 horse-power contracted for locally, and with the probable demands in the near future for other new plants, as well as for extensions to those already installed, it is reasonably certain that from 10,000 to 15,000 horse-power will be required in a year to supply the demands of consumers within a radius of three miles

THE INTERNAL MAKE-UP OF THE CARBORUNDUM CO.'S LARGE STATIC TRANSFORMER. THIS TRANSFORMER REDUCES THE PRESSURE OF THE TWO-PHASE ALTERNATING CURRENT FROM 2400 TO 200 VOLTS.

of the power station. Between Niagara Falls and Tonawanda—a distance of about ten miles—is an open, farming country, which is already being bought up for the purpose of cutting it up for manufacturing sites. Tonawanda itself, which may be considered within the radius of what has been classed as "near-by distribution," has special advantages as a manufacturing centre.

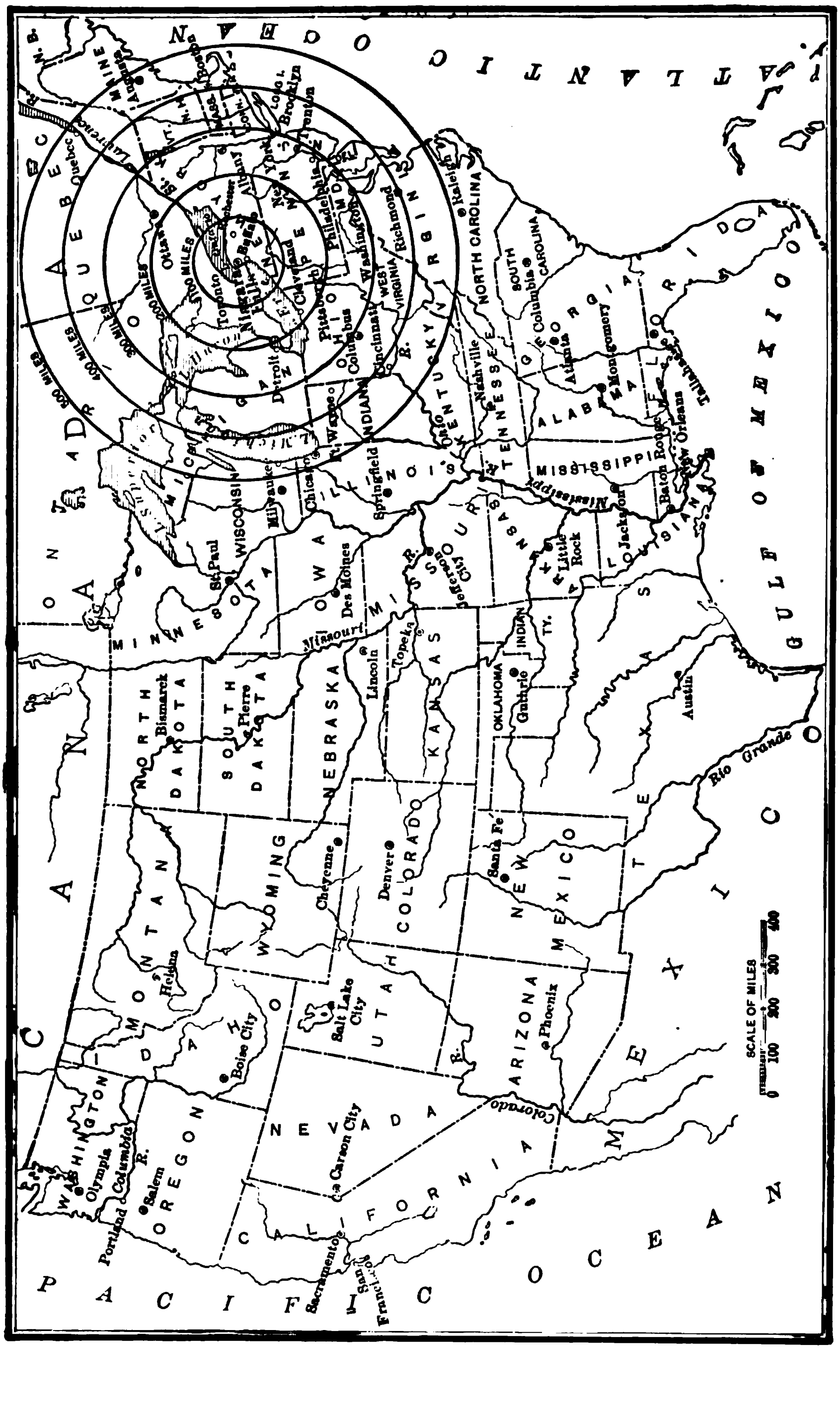
Ten thousand additional horse-power is a reasonable estimate of the power that will be utilized in this territory, so that it seems fair to predict that in five years, with moderately prosperous business conditions, the "near-by" consumers of power will aggregate about 25,000 horse-power. This power will be distributed and used on the general lines already developed in other places, except that the individual consumers will be larger users. No radically new electrical engineering problems are involved, and the cost of distribution will be relatively small. The consumers will reap the benefit of very cheap power, available at any hour, day or night, while the Power Company will be assured of a definite revenue, without the large expenditure necessary for heavy transmission lines and their accessories.

The applications of power thus far suggested or discussed are such as come substantially within the present stage of electrical development, and have little about them, therefore, to cause distrust of their successful outcome, financially or otherwise, even in the minds of those who have given no special attention either to the rapid growth of the electrical art in general or to the development of this great power plant in particular.



THE CARBORUNDUM COMPANY'S ONE THOUSAND HORSE-POWER CURRENT REGULATOR.

We come now to the second and larger phase of the subject—the transmission of the power from Niagara to Buffalo and points beyond, where, in order that its sale may be rendered the more profitable by reason of the quan-



MAP OF THE UNITED STATES, SHOWING THE COMMERCIAL POSSIBILITIES OF NIAGARA POWER.

PUTTING DOWN CABLE CONDUITS AT NIAGARA.

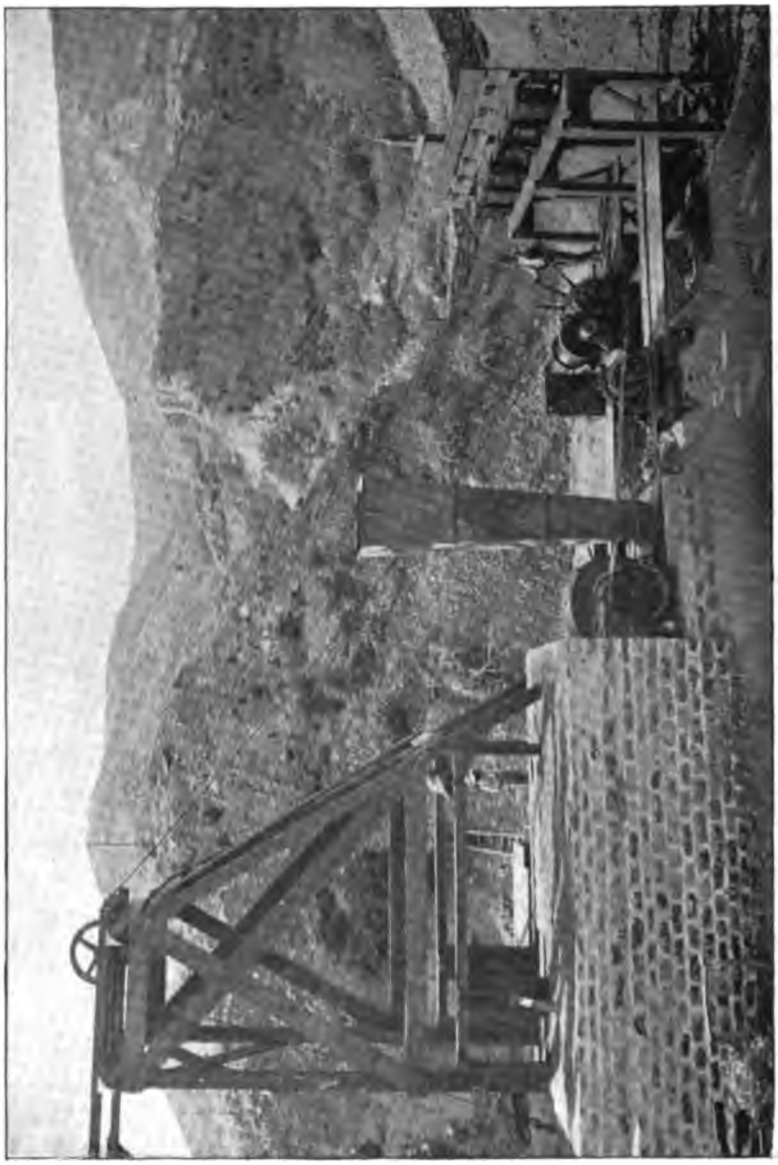
tity consumed, it must successfully displace existing power plants of all descriptions, including even the local electric lighting and railway plants at present operated by steam, and must establish and prove its claim of superior economy and of equal or superior reliability and continuity of service. It is the solution of this problem that demands the attention of electrical engineers, and the results will determine whether the present power house at Niagara, with its ultimate capacity of 50,000 horse-power, shall be only the beginning or the end of the enterprise.

It is instructive to study the map and consider the geographical and commercial possibilities of different areas of distribution, with Niagara as a centre. From this point, on the map shown opposite this page, circles have been drawn with radii of 100, 200, 300, 400 and 500 miles. Table I. gives interesting data of several areas so circumscribed, including areas with the smaller radii of 25, 50 and 75 miles.

TABLE I.

RADIUS IN MILES.	Approximate Area in Square Miles (United States Only).	Number of Cities Within this Area of 5000 People or More	Population of Same (Census 1890)	Approximate Estimate of Horse-Power at Present Used in these Cities.
25	960	4	282,806	69,000
50	2.900	7	305,000	76,750
75	6,300	10	470.000	111,700
100	11,500	16	543,000	143,700
150	27,700	34	825,000	261,500
200	55.500	69	1,756,000	521,000
300	196 000	198	8,246,000	1,967,000
400	272,000	342	11,150,000	2,733.000

About one-fifth of the population of the United States is included within a radius of 400 miles from Niagara. The conditions controlling the commercial delivery of power to a point within any of the areas given depend upon the answers to the following questions:



AN ELECTRIC HOISTING PLANT AT BOLEO, MEXICO.

1. What amount of power can be sold, provided it is delivered? That is, what are the local demands?

2. Are the transmission and delivery to the desired points practicable from an engineering standpoint?

3. If the power can be delivered successfully, can it be sold by the Power Company at such a figure as to compete with the price of power generated locally; that is, compete with the large and economical local power plants, such as electric light and railway stations and city water works, as well as with the small and comparatively wasteful users? The latter class of power consumers are, of course, much more numerous in point of numbers, but not necessarily so in point of amount of power consumed throughout the twenty-four hours.

The first question can be answered only by a local investigation and canvass of the power users, their present consumption and the probable annual growth of this consumption. This latter point is of importance, for the transmission line and transformer stations should be built so as to provide for reasonable growth in demands for a period of from five to ten years. It should not be necessary to erect new buildings, nor to provide new pole lines or conduits for this growth; they should be built of such a capacity as to make it necessary only to install additional apparatus or additional copper wire in the stations or on the pole lines originally provided. The following table gives an idea of the demands for power in some of the principal cities included in Table I. on page 343.

TABLE II.

CITY.	Population, Census 1890.	Distance by Wire from Niagara Falls to City Limits.	Estimated Horse-Power Used.
Buffalo, N. Y	256,000	15	30,000
Rochester, N. Y	134,000	78	25,000
Erie, Pa	41,000	113	8,000
Ashtabula, O	84,000	150	5,000
Syracuse, N. Y	88,000	152	20,000
Utica, N. Y	44,000	203	7,000
Cleveland, O	261,000	213	45,000
Pittsburgh, Pa	239 000	240	65,000
Akron, O	28,000	253	5,000
Schenectady, N. Y	20,000	281	8,000
Sandusky, O	18,500	281	5,000
Albany, N. Y	95.000	309	15,000
Total	......	...	238,000

The second question, regarding the engineering possibilities, is a vital one, and demands careful consideration. Apart from engineering problems pure and simple, it is to be remembered that the transmission line to any of the points mentioned in Table I. must pass through

CROSS SECTION OF A CABLE CONDUIT.

AN ALTERNATING CURRENT INDUCTION MOTOR, GEARED TO A HOIST.

a more or less populous country, and if the necessary voltage or pressure of the current is so high, or if the pole lines and conductors must be of such a size and so placed, that the insulation of the line cannot be maintained, or danger to human life cannot be avoided by any reasonable precaution, then the transmission cannot be considered practicable commercially.

Precedents are always of value in studying the solutions of engineering problems, and it is interesting to consider briefly two remarkable long-distance transmissions of power in successful operation in the United States, although neither are electric transmissions, and each differs materially from the other. One is the transmission of oil by pipe-line, from the natural oil fields of New York, Ohio and Pennsylvania, to tide-water, a distance of over 400 miles. The other is the transmission of natural gas, also by pipe-line, from the Indiana fields to the city of Chicago, a distance of about 120 miles.

The piping of oil, first from the individual oil wells to storage centres, and then from these storage centres to tide-water, has been a process of gradual development for the last thirty years. The necessity for what may be called the "collecting system" of pipes was felt shortly after the discovery of the natural oil wells, and arose from the rough and mountainous character of the oil country, which made the question of transportation an exceedingly difficult one. The individual wells were gradually connected by feed pipes to larger trunk lines, which carry the oil to the storage centres.

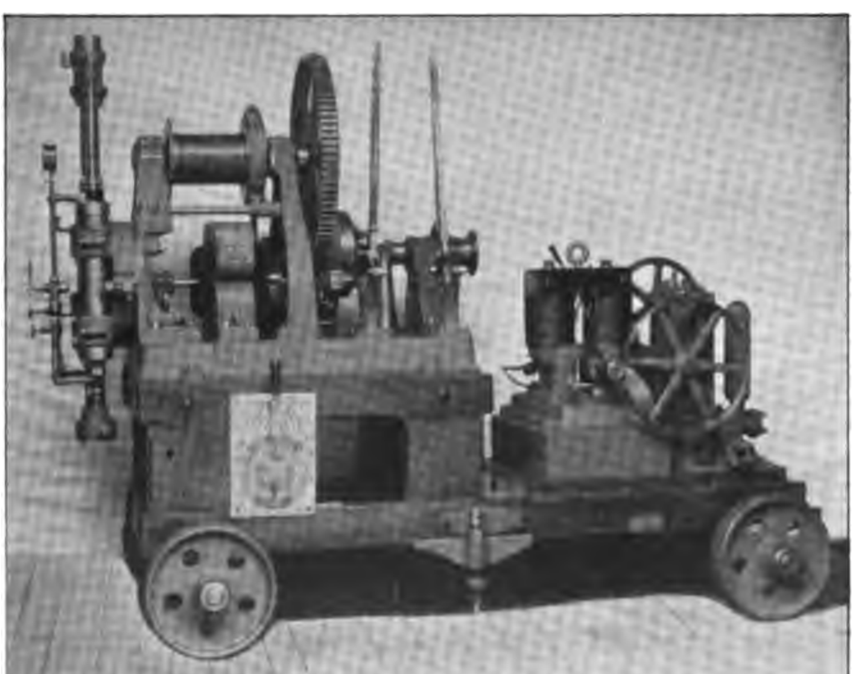
The largest of these centres is at Olean, N.Y., about seventy-five miles from Buffalo. There the Standard Oil Company have large storage tanks, with

an aggregate capacity of nearly 9,000,000 barrels of oil, and from this point starts the great trunk line, composed of three 6-inch wrought iron pipes, running to tide-water in New York harbor, where the oil is loaded into tank steamers and shipped all over the world. There are twelve pumping stations along this trunk line, situated about 35 miles apart, and both the pumps, the pipe-lines and the subsidiary fittings are marvels of mechanical ingenuity and perfection. The pumps operate at a pressure of about 1000 pounds per square inch, and the capacity of the line is about 30,000 barrels a day.

The main pipe-line is divided into divisions and sections, much like a trunk railway system, and has, similarly, its division superintendents and engineers, section foremen, line gangs and line walkers, telegraph stations and daily reports. The system works smoothly and quietly, and as the pipes are buried under ground from one to two feet, and run through a sparsely settled country, the general public sees or hears but little of the system.

A trunk line runs from the Ohio fields to Chicago, another line has been projected from these fields to St. Louis, and two other lines run from West Virginia and Pennsylvania to Philadelphia and Baltimore. The object of the pipe-lines is to cheapen the handling and transportation of oil to the great consumption centres of the country, and while there is no general distribution system at the point of delivery, the line, nevertheless, can properly be considered as a transmission of power on a large scale, where the difficulties of transmission are many and great.

The natural gas pipe line is, perhaps, a more simple example of long-distance power transmission, and bears many striking points of resemblance to transmission by electricity. The Indiana gas field covers a territory in the northern part of the State, about 38 miles long and 18 miles wide. There are about 60 wells in operation, having an



AN ELECTRIC DIAMOND DRILL FOR PROSPECTING WORK.

FRAME OF THE LARGE REGULATOR OF THE CARBORUNDUM CO. (SEE PAGE 339.)

average daily capacity of about 5,000,000 cubic feet each. As in the oil fields, so here, the individual wells are connected by feed pipes to a supply line, which collects the gas and carries it to the pumping-station at Greentown. There large compressors, capable of producing and sustaining a pressure of 2000 pounds per square inch, force the gas into the transmission line to Chicago. The normal pressure carried on this line is 300 pounds per square inch, which admits of a daily delivery of 10,000,000 to 12,000,000 cubic feet of gas in Chicago.

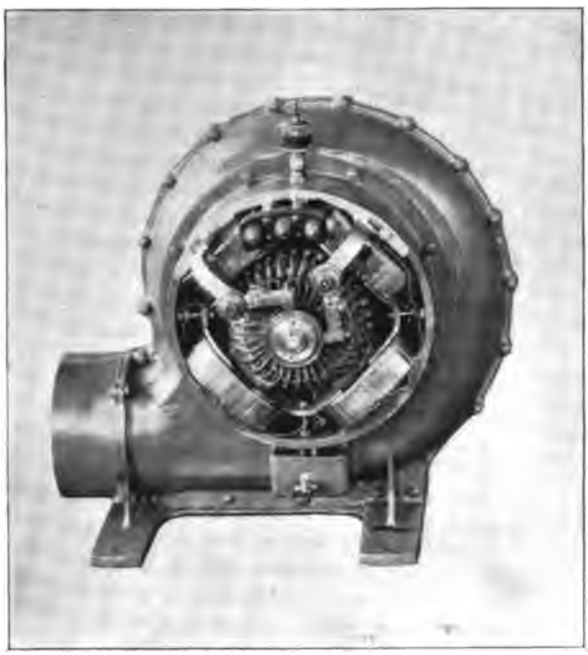
Along the line, which consists of two 8-inch wrought-iron pipes, laid 2½ feet under ground, are located what are known as "by-pass" stations, about 20 miles apart. At the "by-pass" either of the two main lines can be cut off and the gas sent through the other line. The stations are also utilized as headquarters for division superintendents, telegraph operators and repair gangs. At the Indiana State line the pressure

is automatically reduced, in a "regulating station," to 40 pounds, at which pressure the gas is carried into the city by two 10-inch wrought-iron pipes. From these pipes it is fed into an extensive system of distributing mains, throughout the city, the pressure being again reduced to less than 1 pound per square inch. From the city mains the gas is delivered to individual customers for cooking, heating and operating gas engines, and for applying heat under steam boilers, at a price much cheaper than the ordinary illuminating gas.

We have here an example of a great natural force of nature, harnessed by man, carried to a distant point, and there distributed and sold for many purposes and to many customers, at a cost below that of the same force locally produced and distributed. The analogy between the *commercial features* of this transmission and that of the Niagara power (without reference to the means of transmission) is clear and striking, even to the non-professional man. The essential *engineering features* of the natural gas transmission are:

1. An initial station where the gas is collected from the wells and delivered to

2. A pumping station where the *pressure is raised* to a high point, measured by ordinary practice, in order to permit of the transmission of a large volume of the gas a great distance, with a reasonable and practicable size of transmission pipe and loss in transmission.



AN ELECTRICALLY DRIVEN BLOWER.

3. A duplicate transmission line, with stations every 20 miles, where a section of the pipe in use can be cut out for inspection or repairs, the station also serving as headquarters for those in charge of the section.

4. A line construction involving the best material (much of it specially made) and the most careful work of installation, in order to insure continuity of service and immunity from leaks, breaks or other accidents.

5. A "regulating station" at the delivery end, where the high and dan-

A 250 HORSE-POWER THREE-PHASE ALTERNATING CURRENT MOTOR.

gerous transmission pressure is reduced to one that can be safely carried through the crowded streets of a great city.

6. A distribution system in the city by which the gas, transmitted wholesale, is distributed retail to individual consumers.

7. Finally, a complete and thorough organization for the care and preservation of the plant, including, especially, a continuous and minute inspection of the transmission line, with facilities at every "by-pass" station for instant repair ; in short, every facility for the maintenance of the plant in a high state of efficiency and repair.

As will be seen, the analogy between these salient engineering features and those which will distinguish the Niagara transmission is quite as marked as is the commercial analogy already noticed.

Returning now to the engineering problems of the Niagara transmission, the conductors can be carried either overhead, on a pole line of iron or wood, or a combination of iron and wood, or underground, through a subway, where cables are laid or hung in the subway, with a passageway for inspection, or in individual underground pipes or tubes. Where the conductors pass through a city, one or the other of the underground methods will, undoubtedly, be required, but for the main transmission line, across country, it is quite possible to construct an overhead line so substantial as to reduce to a small and unimportant factor the danger to the line from storms of wind, rain, snow or sleet, or from lightning. We have a practical example of such a line in the modern, long-distance, telephone trunk lines, which are the finest examples of line construction anywhere in the world, and some of which are more than 1000 miles in length.

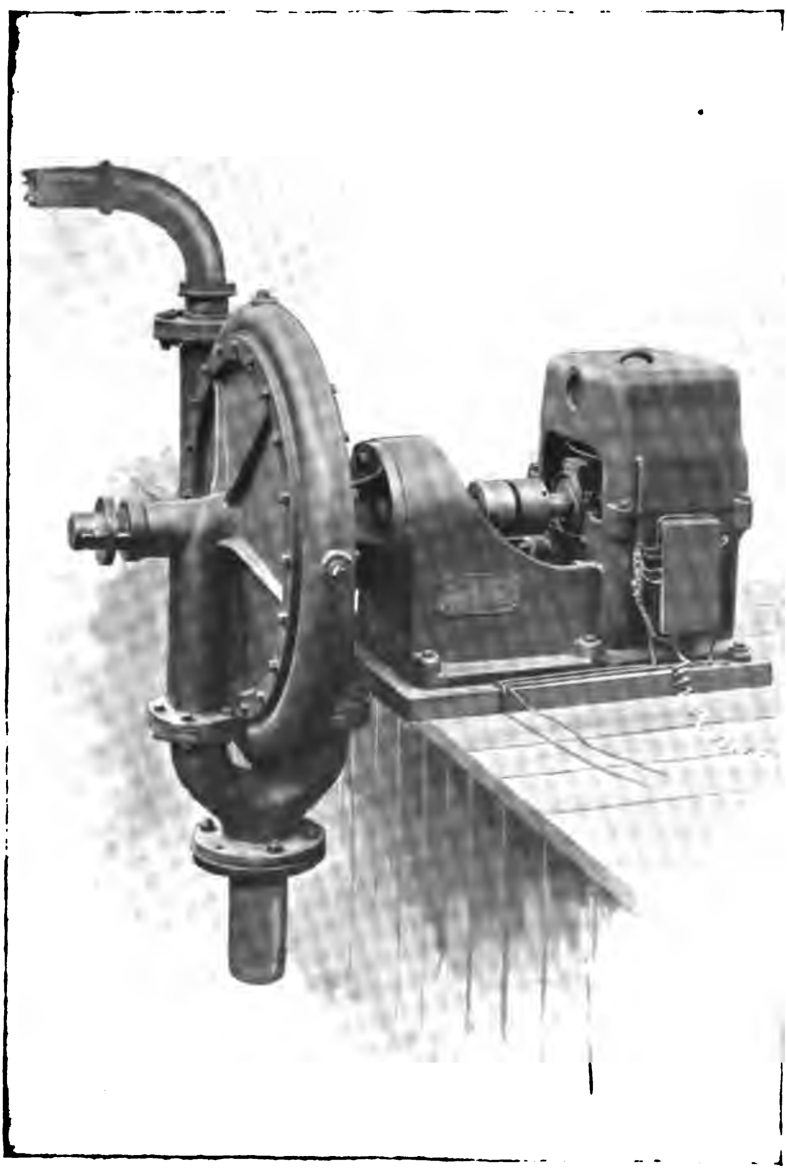
The next important question is the size and insulation of copper conductors necessary. Practical considerations limit the size of a wire for good overhead construction to one having a cross

sectional area of something less than ½ square inch; and if a greater area be necessary, it is divided among two or more conductors. The area of conductor necessary to transmit a given amount of electric power a given distance may be expressed by the equation:

$$A \text{ (area in square inch)} = \frac{C \times N \times D}{E \times V}$$

In this C represents a numerical constant; N the number of electrical horse-power to be delivered; D the length of transmission line, in feet; E the electromotive force (or pressure) at the *delivery end* of the line; and V the loss of pressure in volts on the line, due to its resistance.

This equation applies strictly to direct currents, and while the transmis-



CENTRIFUGAL PUMP WITH DIRECT-CONNECTED MOTOR

TABLE III.

FROM	To	Distance in Miles.	H. P.	Voltage. Generator.	Voltage. Line.	Voltage. Motor.	Remarks.
Lauffen	Frankfort, Germany	105	200	50	40,000	70	Three-phase alt. current plant for Exposition 1892. Various experiments were made on this line.
Water Power	Pachuca, Mexico	23	2,000	700	10,000	....	Three-phase Gen. Elec. Co., under construction.
Water Power	Milan, Italy	19	10,000	....	....	....	Under construction.
Tivoli	Rome, Italy	18	9,000	....	5,000	....	Ganz System, in operation three years.
Water Power	Guadalajara, Mexico	18	350	1,040	11,000	1,000	Three-phase G. E. Co., operated three years at 5,000 v. on line, last three months at 11,000 volts.
River Gorzente	Genoa, Italy	18	1,000	....	8,000	....	Ganz System.
Water Power	Santa Rosalia, Mexico	{ 4½ 9½	20 20 }	2,500	2,500	....	Three-phase G. E. Co., used in mining operations
Water Power	Gringesberg, Sweden	8	400	400	5,000	....	In operation three years.
Lauffen	Heilbronn, Germany	7	200	50	5,000	100	Three-phase, in operation three years.
Richelieu River	St. Hyacinthe, Quebec	5	450	2,500	2,500	....	Three-phase G. E. Co.
Bleio Schwegar	Eucheim, Germany	4	75	2,900	2,900	120	Just complete.
Padenone	Fiume, Italy	3½	100	....	3,000	....	Ganz System.
Folsam	Sacramento, Cal., U. S.	20	3,000	800	11,500	1,000	Three-phase G. E. Co. Co. alt. current, under construction.
Water Power	Telluride, Col., U. S.	15	1,000	5,000	5,000	5,000	Single-phase Westinghouse, in operation four years.
Water Power	Lowell, Mass., U. S.	9 & 14	400	365	5,000	550 D.C.	Three-phase G. E. Co., under construction. Operates St. R. R. by rotary convertors.
Oregon City	Portland, Ore., U. S.	11	10,000	6,000	6,000	133	Ditto.
Mill Creek	Redlands, Cal., U. S	7½	300	2,500	2,500	....	Three-phase G. E. Co., in operation 1½ years.
San Antonio Canon	San Antonio, Cal., U. S.	7	800	....	10,000	1,000	Single-phase Westinghouse.
Baltic	Taftville, Conn., U. S.	4½	400	2,500	2,500	2,500	Three-phase G. E Co., in operation one year.
Sewells Falls	Concord, N. H. U. S.	4	400	2,200	2,200	....	Ditto.
Water Power	Walla Walla, Wash., U. S.	4	100	2,000	2,000	2,000	Single-phase G. E. Co., syn. motor.
Water Power	Canandaigua, N. Y., U. S.	3½	100	2,080	2,080	2,000	Three-phase G. E. Co., under construction.
Water Power	Pelzer, S. C., U. S.	3	1,500	3 300	3,300	3,300	Ditto.
Water Power	Silverton, Col., U. S.	3	125	2,300	2,300	2,000	Three-phase G. E. Co., running three months.
Water Power	Bel Air, Md., U. S.	3	75	2,200	2,200	2,000	Ditto.
Water Power	Hartford, Conn., U. S.	11	300	800	7,000	800	Three-phase G. E. Co., operates station by syn. motor.
Water Power	Columbia Cotton Mills, Columbia, S. C., U. S.	¼	1,340	600	600	550	Three-phase G. E. Co., power distributed by 18 induc. motors.
San Antonio, Cal., U. S.	Pomona, Cal., U. S.	15	150	1,000	10,000	1,000	Single-phase Westinghouse, operates lights in Pomona.
Water Power	Anderson, S. C., U. S.	7	150	5,500	5,500	1,000	Two-phase Stanley Co., operates incandescent lights and induction motors.
Water Power	Mine at Bodie, Cal., U. S.	13	150	3,500	3,500	3,300	Single-phase Westinghouse, Synchronous motor.

Total, 44,105 horse-power.

sion of alternating currents involves certain other losses and disturbances between conductors, they need not be here considered, since they can be practically neglected by a proper arrangement of the conductors in a system such as is here contemplated.

In non-technical language the equation means that the area of conductor, and, hence its weight and cost, varies directly as the horse-power delivered and distance transmitted, and inversely as the electrical pressure at the delivery end of the line and loss of pressure in the line. It follows that the higher we make the delivery, and subsequently

the initial pressure, the smaller and less costly becomes the conductors. The similarity to the laws governing a similar transmission of a liquid, or gas, is noticeable. In the latter case the limit of pressure carried is the strength of the pipe-line and joints; with electricity the limit is the insulation resistance of the conductors. For high pressures, 10,000 volts or more, on an aerial line, insulation material on the outside of a wire cannot be depended upon, for, apart from the fact that it has not a sufficiently high inherent resistance to penetration, the weather soon deteriorates the insulation material, thus lowering its resistance to such a point as to render the insulation practically useless.

The safest and best plan is to use bare conductors, depending upon the supports at the poles for proper insulation. These supports are heavy, "double-petticoated" porcelain insulators, as shown on this page, mounted on the wooden cross-arms of the pole, like the ordinary glass insulators of a telegraph line. Such insulators have successfully withstood a pressure of 90,000 volts before puncture. In such a test, however, actual conditions of weather and atmosphere cannot be fully reproduced, and a safety factor of two is not too large to allow. These insulators are sometimes made in two parts, separated by oil. It is very difficult, however, to keep the oil perfectly clean, and the best practice to-day is to use *air* separation, which, under conditions of service, is probably more reliable than a separation by oil.

SPECIAL PORCELAIN "DOUBLE-PETTICOATED" INSULATOR FOR HIGH-TENSION TRANSMISSION LINES.

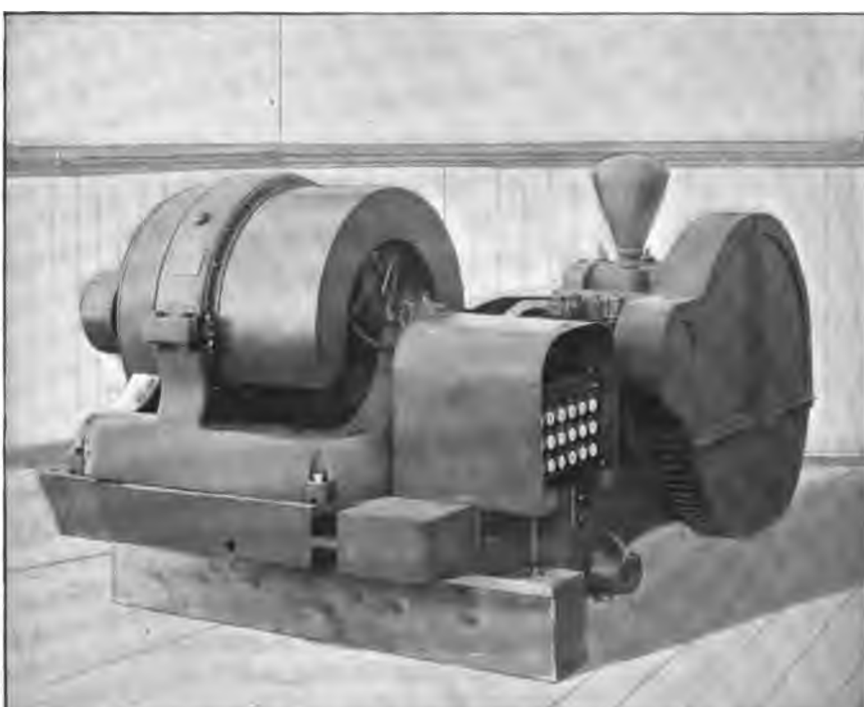
The following list of the principal transmission plants installed or in process of installation elsewhere is interesting as showing what has already been done up to date:

The plant which at once attracts attention in Table III. is the Lauffen-Frankfort transmission of 200 horsepower over a distance of more than 100 miles, and at a maximum line pressure of over 40,000 volts (this in 1892). While it is true that this transmission was on a small scale, comparatively, and while it was more or less experi-

mental in character, it is none the less significant and suggestive of what can probably be done to-day on a large scale with the wider experience and improved methods and apparatus of to-day. The next highest pressure is that on the Guadalajara line, where 11,000 volts are successfully employed. The conductors of the Lauffen-Frankfort line were bare copper overhead wires, attached to oil insulators on the poles, similar to those already described.

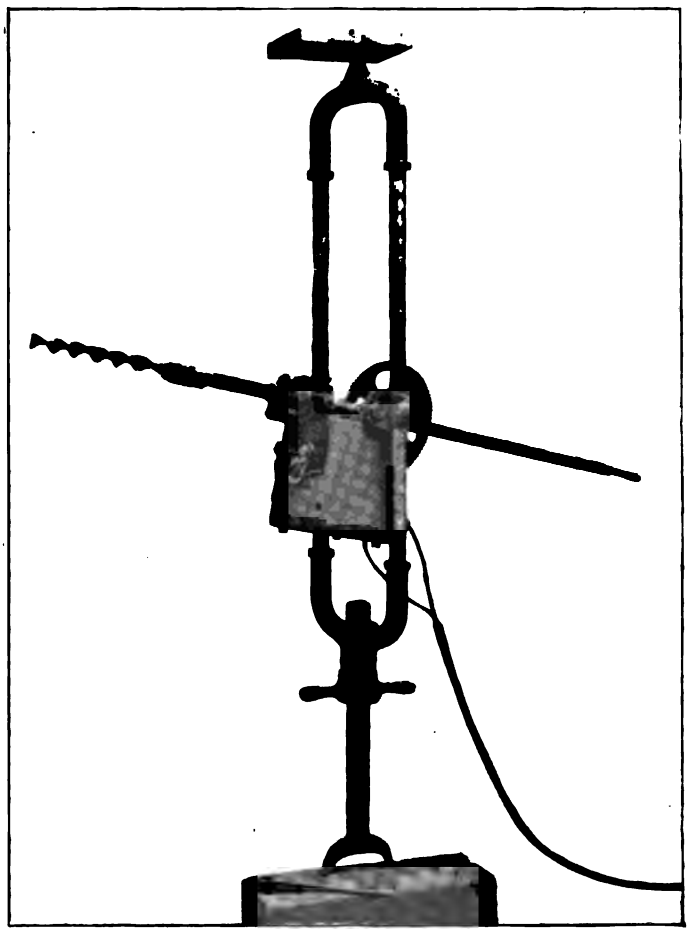
For the transmission of the first 10,000 horse-power to Buffalo from Niagara Falls, it has been practically decided to use 10,000 volts at the delivery end. Connections will be arranged at each end, so that this pressure can be increased to 20,000 volts, if desired. For points beyond Buffalo, it will, undoubtedly, be necessary to raise the delivery pressure still higher, in order to keep the cost of conductors within practicable limits, and for distances of 200 miles or more, the maximum Lauffen-Frankfort pressure of 40,000 volts must be equalled or exceeded. As the increase in the use of Niagara power, however, will necessarily be gradual, the pressure used, and hence the limiting distance of transmission, can be increased as rapidly as experience with lines already installed demonstrates that it is feasible and economical to do so.

Having determined the delivery voltage to be used, the only undetermined factor in the equation fixing the area of conductors, and hence their weight and cost, is the loss of pressure in volts on the line. Obviously we can reduce this loss indefinitely by increasing the area of conductors, but this increase can be carried too far, and the economical point is where the annual charges for interest, depreciation and repairs on the whole line (conductors, pole line and labour of construction) equals the money value of the power lost in transmission. This is known as Kelvin's



A DIRECT CURRENT ELECTRIC MOTOR, GEARED TO A PUMP.

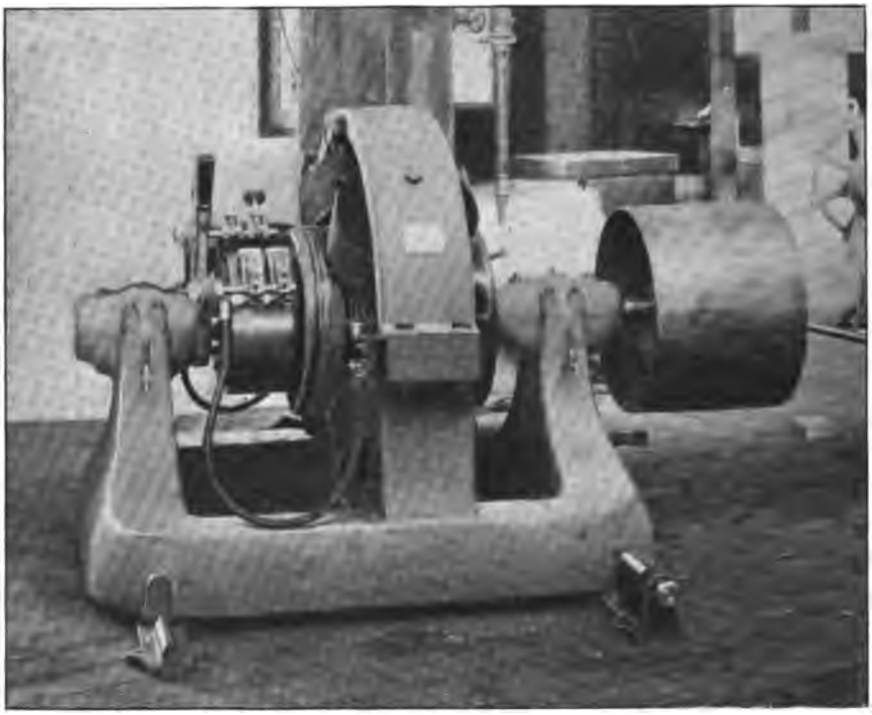
law, and applies strictly where the total line cost increases directly as the increase in area and weight of conductors. This is not usually the case in practice, since the pole line is built with a capacity for additional wires, and the cost of conductors is therefore usually so pro-



AN ELECTRIC ROTARY COAL DRILL.

portioned that the interest on any additional expenditure for copper will not be offset by the money value of the power saved.

It is not practicable at the present time to build either generators or motors which will stand safely the high pressures of transmission here contemplated. It is, therefore, necessary to "step-up" the generator pressure, which may range from 1000 to 5000 volts, to the transmission pressure, and then to "step-down" the latter for delivery and distribution. This is accomplished by large static transformers, similar to those for the Pittsburgh Reduction and Carborundum plants, already described, arranged in units of from 1000 to 2000 horse-power each, in "step-up" and "step-down" stations at each end of the line. The "step-up" and "step-down" stations correspond to the pumping and regulating stations at each end of the natural gas pipe-line.



A MODERN DIRECT CURRENT, SLOW SPEED ELECTRIC MOTOR.

The use of transformers makes it necessary to use the alternating current for long-distance work, and technical questions of current phase and frequency are involved in the engineering problem. A discussion of such questions, however, involves a high technical knowledge, and as their proper relations and proportions are now well understood by technical men, it is not necessary to attempt to discuss them in a paper of this kind.

It is probable that duplicate pole lines and conductors will be installed for any long distance Niagara transmission, and for distances greater than 50 miles, one or more "cut-out" stations along the line will be advisable. The conductors will be led into these stations, and connections will be so arranged that any circuit, or any wire of a circuit, can be cut out for repairs or tests, and the current switched to another circuit. The stations will also serve as headquarters for telegraph operators, division foremen, repair gangs and line-walkers.

The work of a power transmission company ends properly with the delivery of the power, at low pressure, in the "step-down" station. Its local distribution and sale are similar to those of power generated locally, and should be handled by a local company familiar with the people and with local affairs generally. Such companies have already been organized in Buffalo and Syracuse, and will, doubtless, be formed in other cities to which the Niagara power may eventually be delivered. The local engineering problems involved are such as have already been met and solved in central station practice, and need not, therefore, be discussed now.

The illustration on page 358 shows, diagrammatically, the connections of a long-distance transmission such as that to be installed from Niagara to points sixty miles or more distant. Its distinguishing engineering features, and those which will mark a departure from anything heretofore attempted, are: The size of the units (generators, motors

and transformers); the solidity and strength of line construction, and the electromotive force, or electrical pressure used on the line. The last feature is the only one that presents any unknown quantities, and it is really the one which will determine the engineering limit of the distance over which it will be possible to transmit a given amount of power from Niagara.

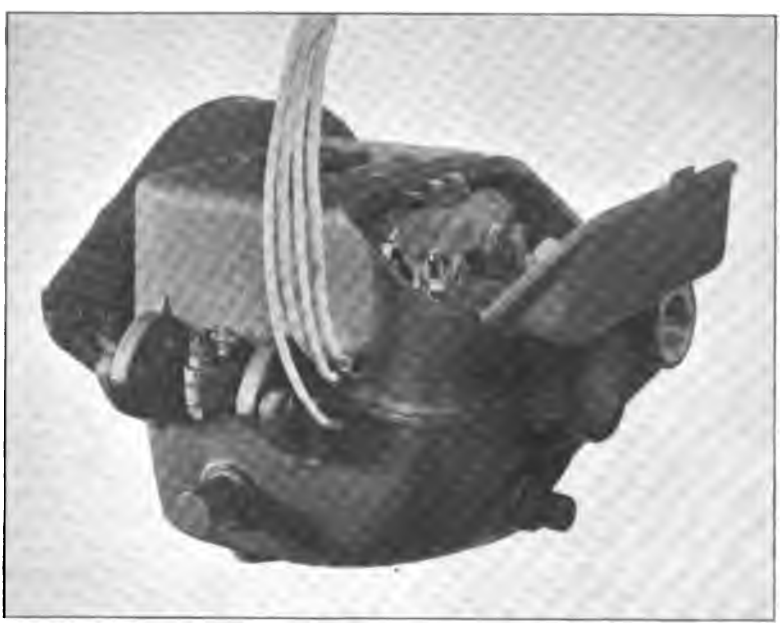
From experiments and tests already made on the Lauffen-Frankfort line, and elsewhere, it does not seem hazardous to predict that a maximum pressure of 50,000 volts at the delivery end of the line will be successfully adopted for long distances, if business conditions warrant the transmission. It is interesting to observe that in the transmission of either oil, gas or electricity, the limiting engineering condition is, in each case, the line pressure that can be safely carried.

One other engineering feature should be mentioned, and that is the efficiency of the apparatus and transmission line. The transformation of energy by electrical apparatus is accomplished with a very small loss, and the efficiency increases with the size of unit employed. For generators, transformers and motors of 1000 horse-power size, or larger, commercial efficiencies, that is the ratio of power delivered to power received, of from 97 to 98 per cent. at full load can be maintained; and as the load varies in a large plant, it will always be possible to keep the units that are in actual operation on full load duty, so as to realize the highest efficiency. The line efficiency

$$\left(\text{ratio } \frac{\text{Power delivered to step-down transformers}}{\text{Power received from step-up transformers.}}\right)$$

will vary with the distance and the pressure on the line. For the most economical conductor cost, the line efficiency will vary, probably, in practice, from 92 per cent. for a Buffalo delivery of, say, 10,000 horse-power, at 10,000 volts (distance 15 miles), to something less than 60 per cent. for an Albany delivery of the same amount of power, at 50,000 volts (distance about 310 miles).

The third, and last question for consideration is the cost of Niagara power, delivered at various distances, as compared with the cost of power produced



A TYPICAL ELECTRIC STREET CAR MOTOR. 25 HORSE-POWER.

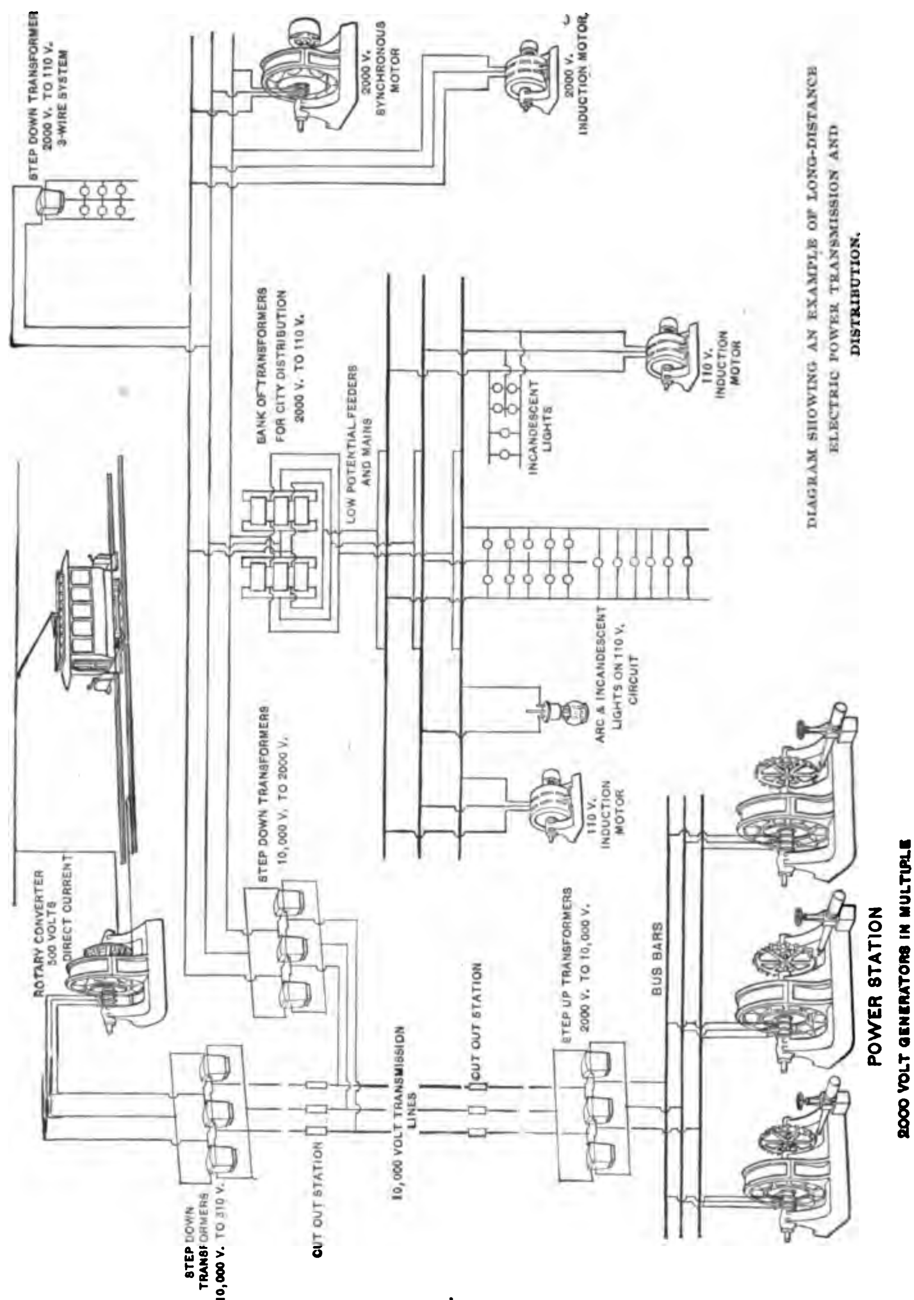
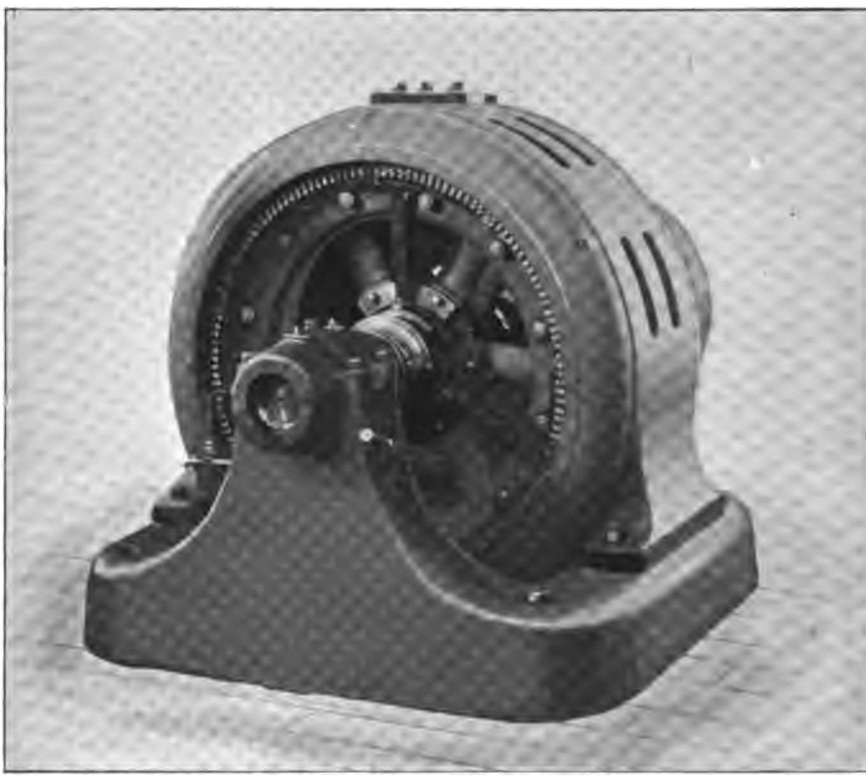


DIAGRAM SHOWING AN EXAMPLE OF LONG-DISTANCE ELECTRIC POWER TRANSMISSION AND DISTRIBUTION.

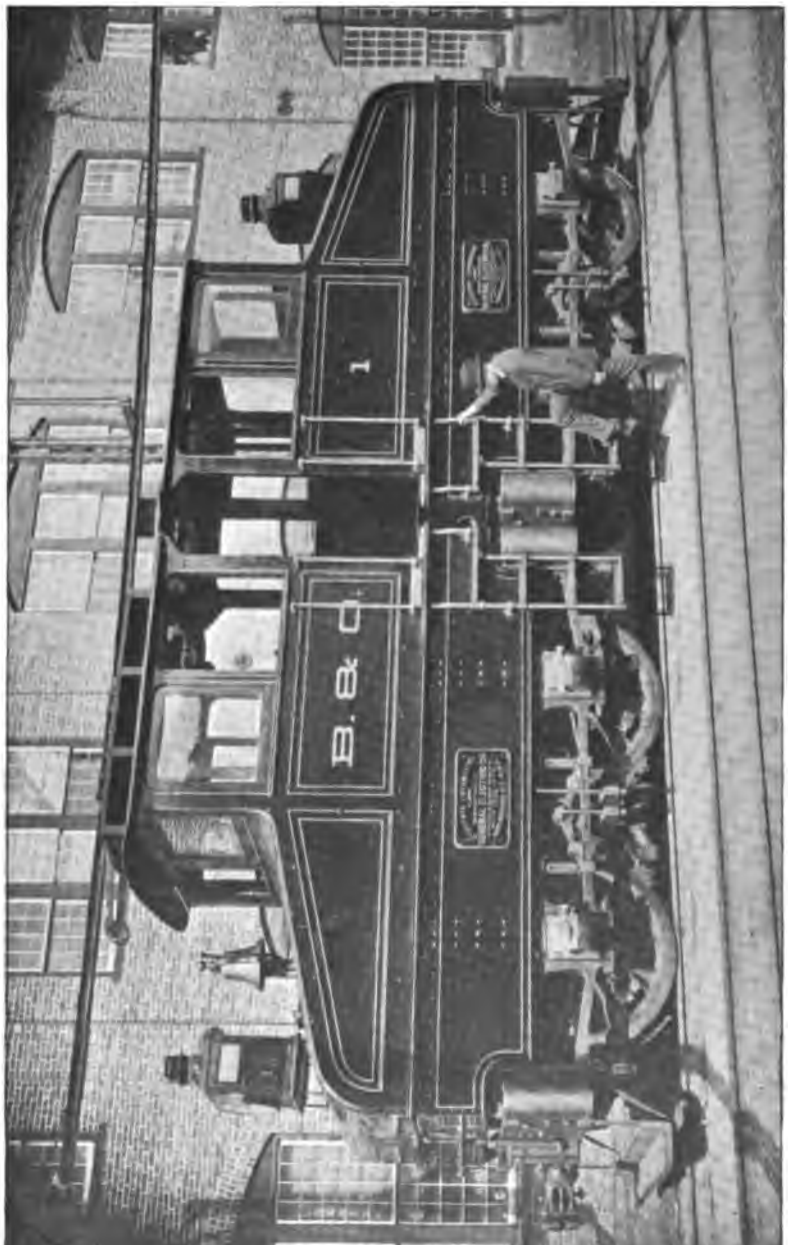
locally; and as steam power is now generally used, either for application to mechanical work direct, or else for driving electric generators, the question is, really, the cost of Niagara electric power, delivered in bulk, versus cost of local steam power. It goes without saying that if a city, as, for example, Rochester, is fortunate enough to possess a reliable water power close at hand, and of sufficient size to provide for most of the city's requirements, Niagara power cannot hope to compete with it.

From recent careful tests, made by disinterested experts, it appears that the cost per horse-power per annum in large and economical steam plants (1000 horse-power or more) in Buffalo, coal costing $1.50 per long ton, is about $33 for power used 11 hours per day, for 365 days a year, or $51 per horse-power for 24-hour power, for 365 days. This cost includes interest on cost of plant, insurance, taxes, operating expenses and depreciation and repairs. As the coal cost is low as compared with other cities, and as the load of the particular plant tested is unusually steady and uniform, it is probable that this cost of steam power is as low as will be found within the area of influence of Niagara electric power. It remains, therefore, to determine the approximate cost of this power, delivered at certain typical points within this area.



A TYPICAL ALTERNATING CURRENT INDUCTION MOTOR OF 125 HORSE-POWER.

About a year ago, there appeared in one of the technical journals, a very interesting and able paper by Messrs. Houston & Kennelly, two well-known American electrical engineers, entitled "An Estimate of the distance to which



NINETY-FIVE-TON ELECTRIC LOCOMOTIVE BUILT FOR THE BALTIMORE AND OHIO R. R., AT BALTIMORE, MD., U. S. A., BY THE GENERAL ELECTRIC CO., NEW YORK.

AN ELECTRIC MINE LOCOMOTIVE.

Niagara water power can be economically transmitted by electricity." Assuming certain initial data, the paper estimated, in detail, the cost of delivery of certain maximum amounts of power to three points, — Buffalo, Syracuse, and Albany,—at assumed distances by wire, from Niagara Falls, of 15, 164, and 330 miles, respectively. These costs were then compared with the cost of steam power, generated locally in large quantity, under most economical conditions, and certain conclusions were drawn from the comparsion. The paper, as was to be expected and desired, created considerable comment and discussion among electrical engineers and in the technical press, and much of the data assumed and some of the conclusions drawn, were publicly criticised or questioned. The critics, however, apparently without exception, failed to appreciate the great difference in cost per horse-power and average efficiency between electric generators, motors and transformers of the size usually employed in central station practice, and those of 1000 horse-power capacity or more which will necessarily be used in the Niagara work.

They also failed to recognize the fact that, inasmuch as Niagara power will be transmitted and sold in bulk in very large quantities, it is reasonable to assume that the "load factor"

$$\left(\text{ratio } \frac{\text{Average load}}{\text{Maximum load}}\right)$$

will be considerably higher than is usual in central station electric lighting practice. The cost of local steam power assumed in the paper was also criticised as being too low, but as the figures were taken from tables carefully prepared and published by a well-known engineer, and as they agreed closely with those obtained from the test

already referred to, they were probably accurate. While some of the data and assumptions used by Houston & Kennelly were, doubtless, subject to correction in detail, they were, in the opinion of the writer, approximately correct, if taken as a whole.

The conclusion to be drawn from their figures is "that on the basis of prices and voltages assumed and detailed, the power of Niagara Falls can be transmitted to a radius of 200 miles, cheaper than it can be produced at any point within that range by steam engines of the most economical type, with coal at 12s., or about $3, per ton; that Niagara power can maintain at Albany, in New York State, a large day and night output cheaper than steam engines at Albany can develop it; but that for power taken at Albany for 10 hours per diem, the best steam engines have somewhat the advantage over Niagara, unless exceptionally favorable conditions of load could be secured for Niagara power."

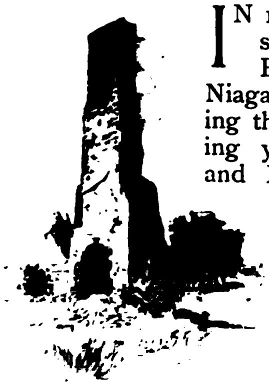
Speaking of electric transmission from water powers in general, Houston & Kennelly say: "The broad conclusion to which an inquiry of this nature inevitably leads, is that while under ordinary conditions the commercial limit of electrical transmission of power from water powers of less than 500 kilowatts can hardly exceed fifty miles, the radius at which it will be profitable, with good fortune and management, to electrically transmit a water power aggregating 50,000 kilowatts, or more, is, perhaps, to-day, two hundred miles, and that it might be commercially advantageous for such a large water power to undersell large steam powers at twice this distance with no profit, in order to reduce the general expense upon delivery nearer home. The reason for this difference in the transmission radius between small and large water powers, lies obviously in the fact that electrical and hydraulic machines can be built and purchased much more economically in large sizes than in small, so that the cost of producing and of maintaining one kilowatt is very much less for large than for small water powers."

While time alone can prove the truth of these conclusions, the writer is of the opinion that, with the present cost and efficiency of steam generators, they are substantially correct. If, on the other hand, a method be discovered for transforming the heat energy of coal into electricity direct, at an efficiency comparable with that of modern electrical apparatus, the area of influence of Niagara electric power will, undoubtedly, be contracted. While such a discovery would undoubtedly be a great one, it should be stated that there is no prospect, at present, of its accomplishment. In any event, it is probable that the Niagara power company will find enough profitable business to insure a satisfactory return on the money which they have invested.

Peter A. Porter is prominently identified with the interests of the city of Niagara Falls. As a member of the New York State Legislature in 1886, he introduced the Niagara Tunnel Bill, under which the Niagara power is now being developed.

THE NIAGARA REGION IN HISTORY.

By Peter A. Porter.



THE OLD STONE CHIMNEY AT NIAGARA, BUILT IN 1750.

IN 1764 Sir William Johnson, commander of the English forces in the Niagara region, supplementing the treaty of the preceding year between England and France, assembled all the Indian warriors of that region, some 2000 in number, comprising chiefly the hostile Senecas, at Fort Niagara, and acquired from them, for the English Crown, together with other territory, a strip of land, four miles wide, on each bank of the Niagara river (the islands being excepted) from Lake Erie to Lake Ontario. The Senecas also ceded to him, personally, at this time, "as proof of their regard and of their knowledge of the trouble which he had had with them from time to time," all the islands in the Niagara river, and he, in turn, as compelled by the military law of that period, ceded them to his Sovereign.

It is of the territory included in the above two grants, a region now popularly known as "the Niagara frontier," that the writer proposes to treat. And a famed and famous territory it is, for it would be difficult to find anywhere else an equal area of country (36 miles long and 8 miles broad, besides the islands) around which cluster so many, so important and such varied associations as one finds there.

Through its centre flows the grand Niagara river, between whose banks the waters of four great lakes,—the watershed of almost half a continent,—find their way to the ocean; and through the centre of the deepest channel of this river runs the boundary line between the two great nations of North America. In it are located the Falls of Niagara, the ideal waterfall of the universe; in it are found the two government parks or reservations, established, respectively, by the State of New York and the province of Ontario, in order that the immediate surroundings of Niagara might be preserved, as nearly as possible, in their natural state and be forever free to all mankind. In it one meets with many and wondrous aspects of natural scenery; in it one finds geologic records, laid bare along the river's chasm by the force of the water thousands of years ago, and which hold so high a place in that science, that among its classifications the name Niagara is applied to one of the groups. In it are found botanic specimens of beauty and rarity, and it is stated that on Goat Island, embracing 80 acres, are to be found a greater number of species and flora than can be found in an equal area anywhere else. In it are to be found, also, the development of hydraulic enterprises which are regarded as stupendous even in this age of marvels; while as to places noted for historic interest, one may truly say that it is all historic ground.

Within sight of the spray of the Falls the red men, in ages long gone by, lived, held their councils, waged their inhuman warfares and offered up their human sacrifices. To this Niagara region long ago came the adventurous French traders, the forerunners of the "coureurs de bois," believed to have been the first white men who ever gazed upon the Falls, though the name of the man to whom that honour belongs, and the exact date at which he saw them will probably forever remain unknown.

Across Niagara's rapid stream went several of the early missionaries of the

THE FIRST KNOWN PICTURE OF NIAGARA FALLS.
(From Father Hennepin's "Nouvelle Decouverte," 1697.)

Catholic church as they carried the gospel to the various Indian tribes in the unknown wilderness. To this region came the French, first officially in the person of La Salle; afterwards, by the armies, seeking conquest and the control of the fur trade. At the mouth of the Niagara river the French established one of their most important posts. There they traded with, conferred with and intrigued with the Indians, making firm friends of some of the tribes and bitter enemies of others; and during the fourscore years that France held sway on the American continent, this region was a famous part of her domain in the new world.

Later on, steadily but surely driving the French before them, and finally totally depriving them of their possessions, came the English. Shortly after England became the undisputed owner of the region, the American Revolution began, and within twenty years after England had dispossessed France of this famous territory, she herself was compelled to recognize a new nation, formed by her own descendants, and to cede to it one-half, or, counting the islands, more than one-half of the lands bordering on the Niagara river. From that time on, the United States and Great Britain have held undisputed possession of all this wondrous section.

Looking back in history for the first references to the Niagara region, we find them derived from Indian tradition or hearsay, and that, almost entirely by reason of the Falls and Rapids. However, it was not their grandeur, but the fact that the Indians were compelled to carry their canoes so many miles around them that impressed them. Thus, the existence of a great fall at this point was known to the Indians all over the North American continent, we know not how far back; certainly as early as the arrival of Columbus at San Salvador.

In 1535 Jacques Cartier made his second voyage to the St. Lawrence, and the Indians living along that river narrated to him what they had heard of the upper part of that stream, and of

the lakes beyond, mentioning, in connection therewith, a cataract and a portage. Lescarbot, in his "History of New France," published in 1609, tells of this in his story of Cartier's voyage. This is the earliest reference (1535) to the Great Lake region and Niagara's cataract.

Champlain, in his "Des Sauvages," published in 1603, speaks of a "fall," which, clearly, is Niagara, and on the map, in his "Voyages," published in 1613, he locates a river with such approximate exactness as to be the Niagara beyond doubt, and in that river he indicates a "sault d'eau," or water-fall.

In 1615 Etienne Brulé, who was Champlain's interpreter, was in that vicinity, in the territory of the Neuter nation, and may have been the first pale-face to have seen the Falls. In 1626 the Franciscan priest Joseph de la Roche Dallion was on the Niagara river in the course of his missionary labors among the Neutrals. It is more than probable that at this date the Niagara route westward, as distinguished from the Ottawa route, was known and had been traversed by white men—the French traders or "coureurs de bois" previously mentioned. In the 1632 edition of his "Voyages," Champlain again, though inaccurately, locates on his map a river which cannot be any other than the Niagara, and quite accurately locates also a "waterfall, very high, at the end of Lake St. Louis (Ontario), where many kinds of fish are stunned in the descent."

In 1640 the Jesuit fathers Brebeuf and Chaumonot undertook their mission to the Neuter nation, the existence of the famous river of this nation having been familiar to the Jesuits before this date. They crossed from the westerly to the easterly shore of the Niagara river, recrossing again, near where the village of Lewiston now stands, when their mission proved unsuccessful. In the Jesuit Relations we find references to this region. In that of 1641, published in 1642, Father L'Allement speaks of "the Neuter nation, Onguiaahra, having the same name as the river," and

FATHER HENNEPIN.
(From an Edition of 1702.)

in that of 1648, published in 1649, Father Ragueneau speaks of "Lake Erie which is formed by the waters from the Mer Douce (Lake Huron), and which discharges itself into a third lake, called Ontario, over a cataract of fearful height."

Sanson in his map of Canada, 1657, correctly locates the lakes and this region, and calls the Falls "Ongiara

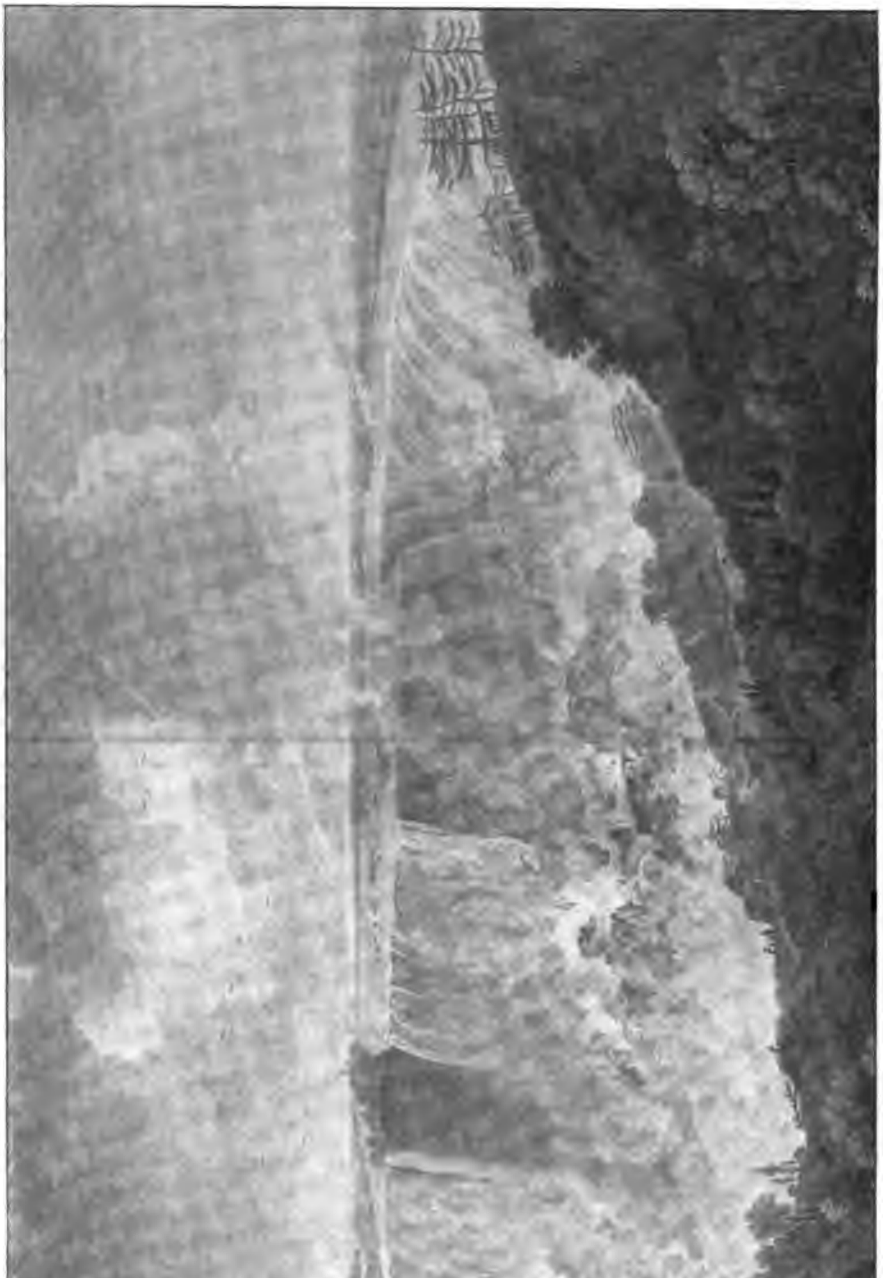
Sault." In Davity, 1660, Le Sieur Gendron refers to the Falls in the exact words of Father Ragueneau above. In his "Historiæ Canadensis," De Creuxius very nearly correctly locates this region and the Niagara river, and calls the Falls "Ongiara Cataractes." In 1669 La Salle made a visit to the Senècas who dwelt in what is now known as Western New York. With him went Fathers Dollier de Casson and René Gallinée, traveling as far as the western end of Lake Ontario, whence La Salle returned eastward. Gallinée's journal of that journey includes the earliest known description of Niagara Falls, which is as follows :

RENÉ ROBERT CAVELIER, SIEUR DE LA SALLE.
(From an Edition of 1688.)

"We found a river, one-eighth of a league broad, and extremely rapid, forming the outlet or communication from Lake Erie to Lake Ontario. The outlet is 40 leagues long and has, from 10 to 12 leagues above its embrochure into Lake Ontario, one of the finest falls of water in the world, for all the Indians of whom I have inquired about it say that the river falls at that place from a rock higher than the tallest pines,—that is, about 300 feet. In fact, we heard it from the place where we were, although from 10 to 12 leagues distant ; but the fall gives such a momentum to the water that its velocity prevented our ascending the current by rowing, except with great difficulty. At a quarter of a league from the outlet where we were it grows narrower and its channel is confined between two very high, steep, rocky banks, inducing the belief that the navigation would be very difficult quite up to the cataract.

"As to the river above the falls, the current very often sucks into this gulf, from a great distance, deer and stags, elk and roebucks, that suffer themselves to be drawn from such a point in crossing the river that they are compelled to descend the falls and are overwhelmed in the frightful abyss. I will leave you to judge if that is not a fine cataract in which all the water of that large river falls from a height of 200 feet with a noise that is heard not only at the place where we were, 10 or 12 leagues distant, but also from the other side of Lake Ontario."

Neither Gallinée, Champlain, nor any of the other writers quoted heretofore, ever saw the Falls. In 1678 Father Hennepin visited the Falls and in 1683 published his first work, "Louisiana," in which he tells of the Niagara river and of the Falls themselves, calling them 500 feet high. On Coronelli's map of 1688 the word Niagara first appears in



THE CATARACT OF NIAGARA, WITH THE COUNTRY ADJACENT.
(From a Drawing taken on the spot by Lieut. Wm. Pierie, of the British Royal Artillery, 1768.)

cartography. In 1691 Father Le Clercq, in his "Establishment of the Faith in New France," uses the words "Niagara Falls." In 1697 Father Hennepin published his "New Discovery," in which he gives the well known description of Niagara Falls, commencing "betwixt the lakes Ontario and Erie there is a vast and prodigious cadence of water which falls down after a surprising and astonishing manner insomuch that the universe does not afford its parallel." Later on, in the same work, he describes them again, giving their height as 600 feet. He also gives in that work the first known picture of Niagara Falls, reproduced on page 366. Hennepin's two works as above, and a third, entitled "Nouveau Voyage," were translated into almost all the languages of Europe and by means of this, as well as by the work of Campanius Holm, published in 1702, who reproduces Hennepin's sketch of Niagara, and by the works of La Hontan, published in 1703, and of others later on, this region and Niagara Falls became familiar to all Europeans. It was reserved for Charlevoix and Borassow, each independently of the other, in 1721, to accurately measure the height of the Falls.

Hennepin was the first to use the modern spelling "Niagara," and he was followed by De Nonville, Coronelli and by all French writers since that time. English writers, on the other hand, did not uniformly adopt this spelling until the middle of the 18th century. The Neuter nation of Indians occupied all the territory now called "the Niagara Peninsula," by far the larger number of their villages being on the western side of the river. It was the Indian custom to give their tribal name to, or to take it from, the chief natural feature of, the country which they inhabited; hence, they were called "Onguiaahra, the same name as the river," as noted by Father Ragueneau. The Neuter nation were so called, because, living between the Hurons on the west and the Iroquois on the east,—two tribes which were sworn enemies,—they were at peace with both, and in their cabins the warriors of these two nations met without strife and in safety. The Neuters, however, were frequently at war with other tribes, and eventually even their neutrality towards the Hurons and the Iroquois disappeared and about 1643 the Senecas, the most westerly and also the most savage tribe of the Iroquois confederacy, attacked and annihilated the Neuters, their remnant being merged into the Iroquois.

There are numerous ways of spelling the Indian name of this Neuter nation, thirty-nine of them being given in the index volume of the Colonial History of the State of New York. The forms most commonly met with in early days were Jagara, Oneagerah, Onygara, Iagara, Onigara, Ochniagara, Ogniogorah, and those previously noted in this article. The word Niagara, according to Marshall, was derived by the French from Ongiara. The Senecas, when they conquered the Neuters, adopted that name as applied to the river and region, as near as the idiom of their language would allow; hence, their spelling, Nyah-ga-ah. The word, thus derived through the Iroquois and from the Neuter language, is said to mean the "thunder of the waters," though this poetic significance has been questioned by some who claim that it signifies "neck," alluding to the river being the connecting link between the two lakes. The Iroquois language had no labial sound and all their words were spoken without closing the lips. They seem to have pronounced it "Nyáh-ga-rah," and later on "Nee-áh-ga-rah," while in more modern Indian dialect, all vowels being still sounded, "Ni-ah-gáh-rah" was the ordinary pronunciation. Our modern word "Niagara" should really be pronounced Ni-a-gá-ra.

Many were the superstitions and legends which the Indians, living along the Niagara river and in the whole region, held as sacred. To the Neuter nation, naturally, the Falls of Niagara appeared in the nature of a divinity. From them they had taken their tribal name, and considered them the embodiment of religion and power. To them they offered sacrifices of many

kinds, often journeying long distances for the purpose. In the thunder of the Falls they believed they heard the voice of the Great Spirit. In the spray they believed they saw his habitation. To him they regularly and religiously contributed a portion of their crops and of the results of the chase, and exultingly offered human sacrifices and trophies on returning from such warlike expeditions as they were compelled to undertake. To him each warrior frequently made offerings of his personal adornments and weapons, and as an annual offering of good will from the tribe and a propitiation for continued neutrality, and therefore existence, they sacrificed each spring the fairest maiden of their tribe, sending her over the Falls in a white canoe, which was filled with fruits and flowers and guided solely by her own hand. The honour of being selected for this awful death was earnestly coveted by the maidens of that stoical race, and the clan to which the one selected belonged, held such choice to be a special honour to itself.

Tradition says that this annual sacrifice was abandoned, because, one year, the daughter of the great chief of the tribe was selected. Her father betrayed no emotion, but on the fateful day, as the white canoe, guided by his daughter's hand, entered the rapids, another canoe, propelled by a paddle in her father's hand, shot swiftly from the bank, followed the same channel and reached the brink and disappeared into the abyss but a moment after the one which bore his daughter. The tribe thought the loss of such a chief in such a way to be so serious a blow that the sacrifice was abandoned in order to prevent the possibility of a repetition. A more likely, but less poetic, reason for its abandonment lies in the belief that on the extermination of the Neuters, their conquerors, having no such inherent adoration for the Great Spirit of Niagara, and for many years not even occupying the lands of their victims, failed to continue the custom. The Neuter warriors also wanted to be buried beside their river, as many exhumed skeletons at various points along its banks prove; and the nearer to the Falls, the greater the honour. Goat Island is said to have been the burying ground reserved for great chiefs and brave warriors, and the body of many an Indian brave lies in the soil of that beautiful spot.

Prior to 1678 France laid claim to a vast area, now embraced by Canada and the northern portion of the United States, east of the Mississippi, including the Niagara region, by reason of early explorations and discoveries by her seamen, traders and missionaries. From that date, when La Salle began his westward journeys of exploration, for eighty years, she was a paramount force in that region, though during the last few years of that period her prowess and supremacy were waning and were swept away in 1659 by the capture of Quebec and Fort Niagara, the latter being the last of the important posts that she held in the long line of fortifications which connected the great tract, known as Louisiana, with her eastern Canadian possessions. From 1759, by occupation, and from 1763, by treaty, England owned all this territory until 1776, when the Colonists demanded recognition as a separate nation. This England conceded in 1783, and thus relinquished all ownership of that portion of the Niagara region that lies east of the river, although it was not until after the ratification of Jay's treaty, in 1796, that England relinquished Fort Niagara; nor until the treaty of Ghent, in 1816, was it absolutely conceded that most of the islands in the Niagara river belonged to the United States.

On December 6, 1678, La Salle anchored his brigantine of ten tons in the Niagara river, just above its mouth. He saw the value, from a military standpoint, of the point of land at the mouth of the river and straightway built there a trading post. Proceeding up the river to where Lewiston now stands, he built there a fort of palisades, and carrying the anchors, cordage, etc., which he had brought with him for that purpose, up the mountain side and through the forest to the mouth of Cayuga creek, five miles above the Falls on

THE WHITE MAN'S FANCY.

THE RED MAN'S FACT.

THE BUILDING OF THE GRIFFON, 1679.
(Fac-simile reproduction of the original copper-plate engraving, first published in Father Hennepin's "Nouvelle Decouverte," Amsterdam, 1704.)

the American side, where to-day is a hamlet bearing his name, he there built and launched the Griffon, the first vessel, other than Indian canoes, that ever sailed the upper lakes, and the pioneer of an inland commerce of untold value.

In 1687, the Marquis de Nonville, returning from his expedition against the Senecas, fortified La Salle's trading post at the mouth of the river, but it was abandoned during the following year. It was, however, rebuilt in stone in 1725 by consent of the Iroquois, and thereafter maintained. The site of the present village of Lewiston, named in honour of Governor Lewis of New York,—the head of navigation on the lower Niagara,—was the commencement of a portage of which the upper terminus was about a mile and a half above the Falls, the road traversed being, even now, called the "portage road." The upper end of this portage, at first merely an open landing place for boats, necessarily grew into a fortification, which was completed in 1750 and was called Fort de Portage, or, by some, Fort Little Niagara. A short distance below the site of this fort the French built their barracks. These and the fort itself were burnt in 1759 by Joncaire, who was in command, to prevent their falling into the hands of the victorious English, and he and his men retreated to a station on Chippewa creek, across the river. An old stone chimney, believed to be the first stone structure built in that part of the country, and around which were built the French barracks, stands to-day solitary and alone, the only reminder of the early commercial and military activities at this point.

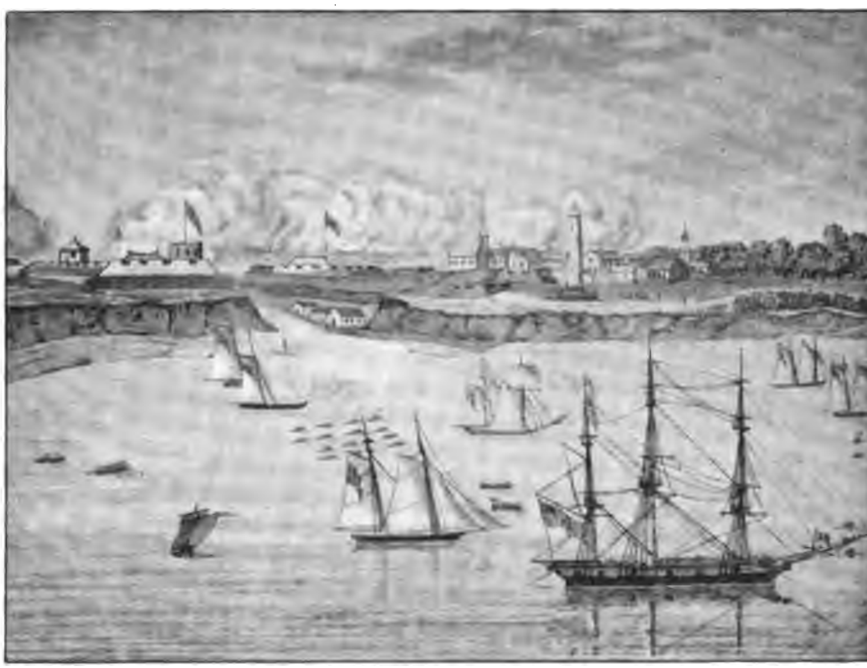
It was in 1759 that the English commenced that short, memorable and decisive campaign which was forever to crush out French rule in North America. General Prideaux was in charge of the English forces thereabouts, and, carrying out that part of the plan assigned to him, collected his forces east of Fort Niagara on the shore of Lake Ontario. That fort had been strongly fortified, and this fact, coupled with its location, made its capture necessary for English success. Prideaux's demand for its surrender having been refused, he laid siege to it. He was killed during the continuance of the siege, and the command devolved on Sir William Johnson, who pushed operations vigorously

and captured the fort before French reinforcements could arrive.

These reinforcements had been sent from Venango, on Lake Erie, and, coming down the Niagara river, had reached Navy Island (Isle de Marine), then held by the French, when they heard of the fall of Fort Niagara. The certainty that the two vessels which had brought the troops and ammunition from Venango would be captured by the English, induced the French to take them, together with some small vessels which had recently been built on Navy Island, over to the northern shore of Grand Island, lying close by, into a quiet bay, where they set them on fire and totally destroyed them. As late as the middle of the present century, portions of these vessels were clearly visible under water in the arm of the river, which, from this incident, has become known as "Burnt Ship Bay."

One more historical point, the scene of the Devil's Hole massacre, is connected with the great French and English struggle. Champlain's early hostility to the Iroquois, when he sided with the Senecas against them, had made the Iroquois the firm friends of the English during all the subsequent years, and it had also endeared the French to the Senecas, even though the latter had subsequently joined the Iroquois confederacy.

After the total defeat of the French and their practical surrender of all their territory in 1759, the old hatred of the English on the part of the Senecas, abetted, no doubt, by French influences, led them to commence a bloody campaign against the English in 1763. They knew the English were, on a certain day, to send a long train of wagons, filled with supplies and ammunition, from Fort Niagara to Fort Schlosser, a station, built in 1761 by Capt. Joseph Schlosser of the English army, to replace Fort de Portage, which had been destroyed two years pre-



THE CAPTURE OF FORT GEORGE, 1813.
(From an Old Engraving.)

viously. They knew also that the military force accompanying the train was to be a small one. At a point, known as the Devil's Hole, about three miles below the Falls, and at the edge of the precipice, they ambushed this fated supply train and destroyed it, forcing both train and escort over the high bank, and killing all but three of the escort and drivers. They then cunningly ambushed the relief force, which at the sound of the firing had set out from Lewiston where the English maintained a slight encampment, and killed all but eight of these. It was a striking example of Indian warfare and of Indian shrewdness. Shortly after this, in 1763, the treaty between France and England was signed, whereby England became the absolute owner and master of the northeastern portion of the North American continent.

No serious conflict marked England's rule in her new territory, acquired by so long and fierce a struggle and at so great a cost of lives and money. But thirteen years after the above treaty was signed, the American Revolution commenced. Had Gen. Sullivan's expedition against the Senecas in 1779, been successful, as planned, he would have pursued the dusky warriors who fled to Fort Niagara, and would have attacked and probably captured that fort, then in possession of the English ; but misfortune befel him on his westward march, and the Niagara region was never the scene of actual hostilities during that war. When it closed, England had lost and relinquished to the United States all that portion of this region that lies east of the Niagara river.

The Niagara region, especially that part lying along the banks of the river, felt the full burden of the three years of border warfare between American and English forces, each with their Indian allies, known in history as the war of 1812. In the fall of 1812, about four months after the declaration of war, Gen. Van Rensselaer established his camp just east of the village of Lewiston, and collected an army for the invasion of Canada. After some delay and one unsuccessful attempt to cross the river, many of his men reached the Canadian shore and promptly and easily occupied an advantageous position on Queenston Heights. Gen. Brock hastened from Fort George, at the mouth of the river, with English reinforcements, and, in endeavoring to recapture this point of vantage, was killed at the head of his troops. Other English reinforcements having arrived, the Americans were defeated and dislodged from their position, many being forced over the edge of the bluff. Most of these and many on the brow of the mountain were taken prisoners. Meanwhile, directly across the river, on the American side, in full view of the battle, were several hundred American volunteers who basely refused to go to the aid of their companions.

The results of this first battle were most depressing to the American cause. At the foot of Queenston Heights an inscribed stone, set in place in 1860 by the Prince of Wales with appropriate ceremonies, marks the spot where Gen. Brock fell, and on the heights above a lofty column was erected to his memory in 1826, as a monument of his country's gratitude. This was blown up by a miscreant in 1840, but was replaced in 1853 by the present more beautiful shaft, within whose foundations Gen. Brock's remains lie buried.

It was in November, 1812, that Gen. Alexander Smythe, of Virginia, commanding the American army on this frontier, issued his famous bombastic circular, inviting everybody to assemble at Black Rock, near the source of the Niagara river and to invade Canada. "Come in companies, half companies, pairs or singly; come anyhow, but come," was its substance, and about 4000 men responded. But Smythe proved incapable, and having made himself a laughing-stock in many ways, among others in challenging Gen. Porter, who had questioned his courage, to a duel (which challenge was accepted and shots were exchanged on Grand Island), the contemplated invasion was abandoned.

In May, 1813, the Americans captured Fort George and the village of Newark, both on the Canadian shore

near the mouth of the river, and held them until December of that year. So effectual was American supremacy at this time, that the English Fort Erie, at the source of the river, and Chippawa, just above the Falls, together with all barracks and store houses along the river, were abandoned, and the English evacuated the entire frontier. Fort Erie was promptly occupied by the Americans. Several minor attacks were made by small parties of English at points on the American side during 1813, one at Black Rock, where the English were badly repulsed, being the most important.

In December, 1813, the British assumed the offensive on their side of the river and soon Gen. McClure, who was in command of the American forces holding Fort George, determined to abandon it and cross to Fort Niagara. He blew up Fort George and applied the torch to the beautiful adjoining village of Newark. This was the oldest settlement in that part of Canada, was at one time the residence of her lieutenant-governor, and was further noted as the place where the first Parliament of Upper Canada was held in 1792. Its destruction was in the line of military tactics which leaves nothing to shelter an enemy when they occupy evacuated ground; but it was a severe winter, the snow was deep, and the sufferings of those whose homes were thus burnt, were excessive.

The burning of Newark raised a storm of wrath throughout Canada and England which stimulated the English forces to make great efforts for victory and retaliation. In these they were decidedly successful, for ten days later, at three o'clock in the morning, Col. Murray, of the British Army, surprised and captured Fort Niagara. Had Capt. Leonard, who was in charge of the Fort while Gen. McClure was at his headquarters in Buffalo, been vigilant, the Fort would have, probably, been successfully defended. As it was, it fell an easy prey. Lossing says: "It might have been an almost bloodless victory had not the unhallowed spirit of revenge demanded victims." As it was, many of the garrison, including invalids, were bayonetted after all resistance had ceased. The British General Riall, with a force of regulars and Indians was waiting at Queenston for the agreed signal of success, and when the cannon's roar announced the victory, he hurried them across the river to the village of Lewiston, which was sacked and destroyed in spite of such opposition as the few Americans in Fort Gray on Lewiston Heights could make.

After a temporary check on Lewiston Heights the British pushed on to Manchester (that name having been given to it in anticipation of its ultimately becoming the great manufacturing village of America) as the settlement at the Falls was then called. That place, the settlement at Schlosser, two miles above, and the country for some miles back shared the fate of Lewiston; the same was meted out to Youngstown, near Fort Niagara. The destruction of the bridge across the creek at Tonawanda saved Buffalo from the same fate, but only for a few days. Gen. Riall crossed the river at Queenston, and a few days later appeared opposite Black Rock which adjoined Buffalo. This he promptly attacked and captured. The hastily gathered and unorganized American forces not only offered little resistance, but hundreds deserted. Buffalo was burnt, only four houses being left standing, and many persons were killed.

The opening of the campaign of 1814 found an American army at Buffalo, and on July 3, Fort Erie surrendered to the Americans. On July 5, the Americans met and, after a fierce fight, defeated the British in the memorable battle of Chippawa, on the Canadian side, two miles above the Falls. Soon afterwards, the British retreated to Queenston, followed by the Americans under Gen. Brown, who then determined to recapture Fort George; but learning that the expected fleet could not co-operate with him, he changed his plans and returned to Chippawa. Gen. Scott, reconnoitering from this place in the late afternoon of July 25, found Gen. Riall with his re-

inforced army drawn up in line of battle at Lundy's Lane. Gen. Scott, with a nominal force, but with the hope of gaining time for the advent of Gen. Brown's army, immediately gave battle. Of the details of that battle, fought mainly by the glorious light of a summer moon, and continued until after midnight, with the spray of Niagara drifting over the heads of the opposing armies and the thunder of the Falls mingling with the roar of the cannon, it is not possible to recount much. The central point on the hill was held by a British battery, and it was in response to an order to capture it that Col. Miller made his famous reply, "I'll try, Sir." He did try, and successfully, and the battery, once captured, was held by the Americans against oft-repeated and brave attacks by the British.

When at last the British army retreated, the Americans fell back to their camp at Chippawa, and before they returned the next morning, the British had once more, owing to the American General Ripley's negligence, occupied the field and dragged away the cannon which had been captured from them. The battle of Niagara Falls, Lundy's Lane, or Bridgewater as it is variously called was claimed as a victory by the British, and is still annually celebrated, on the battlefield, as such. The Americans, too, regarded it as a substantial victory, and the United States Congress voted to Generals Scott, Brown, Porter, Gaines and Ripley gold medals for their services in this and other battles of the war.

The American army now returned to Fort Erie which they strongly fortified, and where they were besieged on August 3, by the British. For ten days both armies were busy preparing for the inevitable and decisive contest. Just after midnight on August 14, the British attacked the fort, but were finally repulsed. From this time to September 17, there was frequent cannonading, but on that date a sortie from the fort was made by the Americans, and was so boldly planned and so faithfully executed, that the British were completely routed, and Buffalo and Western New York saved from invasion. Lord Napier refers to this sortie as the only instance in modern warfare, where a besieging army was totally routed by such a movement. A few more desultory engagements occurred along the Canadian bank of the river, Gen. Izard having assumed command of the American army; but the season was too far advanced for any further offensive operations on this peninsula, and Canada was abandoned. Fort Erie was mined, and on November 5, 1814, was laid in ruins. It still remains so,—a picturesque spot. Some space has been devoted to this war, although not a fraction of what its importance demands. During its continuance almost every foot of land along both banks of the Niagara river was the scene of strife, of victory and defeat, of triumphs of armies and of bravery and heroism of individuals.

The treaty of Ghent restored peace to both countries, to the delight of all, especially of the inhabitants along the frontier. The commissioners appointed under that treaty to settle the question of the boundary between the United States and Canada agreed subsequently that that line, "between Lake Erie and Lake Ontario should run through the centre of the deepest channel of the Niagara river, and through the point of the Horse Shoe Fall." Later years proved this to be a variable line as far as the point of the Fall is concerned, though this fact will never impair the validity of the boundary line. By the above decision Grand Island and Goat Island became American soil, and Navy Island fell under British rule. The frontier, especially on the American side, recovered rapidly from the effects of the war, for it was a section sought by settlers, and many who reached the Niagara river on a projected journey to lands farther west, became residents of the locality.

Prior to 1825, all heavy goods were sent westwards by Lake Ontario vessels to Lewiston; thence, were carted over the well-known "Portage road" to Schlosser, and there again reloaded into vessels which went up the Niagara

river, past Black Rock and Buffalo at the source of the river, and then out into Lake Erie. Freights from the west followed the opposite course, over the same route; and this carrying trade along the frontier, controlled almost entirely by one firm, was a source of personal wealth to its members, a means of livelihood to many a family, and a prominent factor in the speedy development of the region. On October 26, 1825, a cannon in the village of Buffalo, at the source of the Niagara river boomed forth its greeting, followed, a few seconds later, by another cannon, near Black Rock; and thus thundered cannon after cannon, down the Niagara river, to Tonawanda; thence, easterly to Albany, and south, along the Hudson river, to New York city, announcing the glad message that, at the source of the Niagara river, the waters of Lake Erie had just been let into that barely completed water-way, the Erie Canal. The completion of the canal built up Buffalo, but at the same time, checked the rapid growth of the northern portion of the region, by causing a total suspension of traffic over the old portage.

Two events, entirely dissimilar and in no way connected with warlike operations, occurred in this region in the year 1826, and each attracted the attention of the whole world. The first was the proposal of Major Mordecai M. Noah to create a second City of Jerusalem within clear view of the Falls of Niagara, by buying Grand Island, comprising some 18,000 acres, and there building up for the Hebrew race an ideal community of wealth and industry. He even went so far, in his assumed capacity of the Great High Priest of the project, as to lay the corner stone of the future city of Ararat. This he did, not even within the boundaries of his proposed city, but some miles away, on the altar of a Christian church in Buffalo, to which church, clad in sacerdotal robes, attended in procession by military and civic authorities, local societies, and a great concourse of people he was impressively escorted. The Patriarch of Jerusalem, however, refused his sanction to the project, money did not pour in to its support, and it was ultimately abandoned. The corner stone was, however, built into a small brick monument at White Haven, a point on Grand Island opposite Tonawanda, and is now in the rooms of the Buffalo Historical Society.

The other event was the reputed murder of William Morgan, of Batavia, who had threatened to disclose the secrets of the masonic fraternity in print. He was quietly seized and taken away from his home, and was traced, in the hands of his abductors, through Lewiston, to Fort Niagara. There he was confined in what is still called "Morgan's Dungeon," a windowless cell that was probably used as a powder magazine. All trace of him was lost after he entered the fort, and tradition says he was taken from his dungeon by night, placed in a boat, to be sent, as he was told, to Canada, rowed out on Lake Ontario, and forced into a watery grave. Several persons were arrested and tried for his murder, but no proof of their being directly concerned in the matter, nor, in fact, any direct proof of Morgan's death being introduced, they were discharged. Some persons, however, were sentenced to imprisonment for conspiracy in connection with the matter. Thus the episode upon which the famous, powerful and widespread anti-masonic agitation was based, occurred in, and became an integral part of Niagara's history.

In the same year, the first survey and report were made at Lewiston on a project, which, so far as any commencement of it is concerned, is now as remote as it was then. Yet, it is a project which has a national importance, on which, in at least four surveys, the United States Government has employed some of its greatest engineers, and one which has, on numerous occasions, been discussed and advocated by commercial bodies, and in the halls of the United States Congress; namely, a ship canal, of a capacity large enough to float the largest war vessels around the Falls of Niagara. From a point from two to four miles above the Falls, to the deep and quiet waters near

Lewiston, has been the route most generally approved for such a canal, of which the cost would be enormous. The resulting benefits, however, especially as the population and wealth of the United States increase, might be inestimable, especially in the event of a war with England and Canada.

The Niagara region again became the theatre of war in 1837, when the Patriots undertook to upset the Government of Canada. While the first revolt occurred at York, now Toronto, the entire Canadian bank of the Niagara river was kept in a ferment for several months. Navy Island was at one time the principal rendezvous of the Patriots, and from there, on December 17, 1837, William Lyon Mackenzie, the leader, signing himself "Chairman pro tem of the provincial (a printer's error, which should read provisional) government of the State of Upper Canada," issued his famous proclamation to the inhabitants of the Province.

Without reference to the various intrigues carried on all along the frontier by the Patriots with their American sympathizers, of whom there were, doubtless, a goodly number, the writer would mention only the crucial event of the war, the Caroline episode. It was openly charged by the Canadians that substantial aid was being rendered from the American side to the Patriots, both by private individuals in various ways, and especially by reason of the non-interference of the national and New York State authorities when informed, on credible testimony, that arms and amunition were being shipped and other aid was being furnished from American soil to the Canadian rebels. This feeling was so bitter on the part of the English that it is not surprising that they seized the first opportunity for retaliation.

A small steamer, the Caroline, had been chartered by some people in Buffalo to run between that city, Navy Island where the insurgents were encamped, and Schlosser, on the American side, where there was a landing place for boats and a hotel. They maintained that it was a private money-making venture, transporting the sightseers to the Patriot's camp; but from the Canadian's view the real object was to convey provisions and arms to their enemies. On the night of December 29, 1837, the Caroline lay moored at Schlosser dock. The excitement of the rebellion had drawn many people to this locality, the little hotel was filled and some persons had sought a night's lodging on the boat.

At midnight, six boats, filled with British soldiers, sent from Chippawa by Sir Allan McNab, silently approached the Caroline. The soldiers promptly boarded her, drove off all on board, both crew and lodgers, cut her adrift, set her on fire, and again taking to their boats, towed her out to the middle of the river and cast her loose. And a glorious sight, viewed merely from a scenic standpoint, it was. The clear dark sky above and the cold dark body of water beneath. Ablaze all along her decks, her shape clearly outlined by the flames, she drifted grandly and swiftly towards the Falls. Reaching the rapids, the waves extinguished most of the flames; but, still on fire, racked and broken, she pitched and tossed forward to and over the Horse Shoe Fall, into the gulf below. The whole affair, the incentive therefor, the methods employed, and the manner of the attack caused intense excitement, and once again the Niagara frontier was threatened with war, and the militia along the border were actually called into the field.

Long diplomatic correspondence followed, the British Government assuming full responsibility for the claimed breaches of international law and the acts of her officers. During the melée at the dock, one man, Amos Durfee, was killed. A British subject, Alexander McLeod, claimed to have been one of the attacking force, was soon after arrested on American soil and was tried for the murder in New York State, but was finally acquitted. War was wisely averted, but another fateful chapter had been added to Niagara's history.

With the exception of the Fenian outbreak on the Canadian side of the

river in 1866, the region has been free from war's alarms since the days of the Patriots. The Fenian outbreak was one of the results of the plan of the revolutionary Irishmen to oppose the English Government, and to compel that government to restore Ireland's rights. The Fenian hostility to Canada was solely because of the fact that the latter was an English dependency. The special time was selected, because of the actual service that many loyal Irishmen had just then seen in the United States army during the Rebellion. Of actual hostilities on this frontier there was but one occurrence during the brief agitation, fought on the Canadian side opposite Buffalo, from which city the Fenians invaded Canada. It was known as the battle of Ridgeway, the main contest having been at that point, with a subordinate engagement at a hamlet called Waterloo, close to the water's edge. The Fenians were temporarily successful, but were ultimately entirely defeated and their invading force quickly dispersed.

In 1885, the State of New York, after an agitation by prominent men for several years, purchased the land on the American side, including Goat Island and all the smaller islands adjacent to the Falls, and above and below them, for a State Reservation. In 1887, the Province of Ontario, Canada, took a similar action. The Canadian Government, many years ago, with rare foresight had reserved a strip of land, sixty-six feet wide, along the water's edge above the Falls, and along the edge of the high bank below them, from Lake Erie to Lake Ontario, as a military reserve. This is now under the control of the Canadian Park Commissioners, and, together with the additional lands acquired near the Falls, and the land around Brock's Monument, forms an ideal government reservation.

THE STEAMER CAROLINE BURNT AND FORCED OVER THE FALLS ON DECEMBER 29, 1837.
(From an Old Engraving.)

The honour of first suggesting the preservation of the scenery about the Falls has been claimed for many persons. Others, later on, suggested it officially; others still, advocated it more publicly and more persistently,

A RECENT VIEW OF NIAGARA FALLS.

but the first real suggestion, though made without any reference to details, came from two Scotchmen, Andrew Reed and James Matheson, who, in 1835, in a work describing their visit as a deputation to the American churches, first broached the idea that "Niagara does not belong to Canada or America. Such spots should be deemed the property of civilized mankind, and nothing should be allowed to weaken their efficacy on the tastes, the morals, and the enjoyment of men."

Such, in the ordinary acceptation of the word and in the briefest form, is an outline of the history of the Niagara region. Many points and facts of interest have necessarily been left untouched, but brief reference should be made to the old tramway, built from the water's edge, at the very head of navigation on the lower river, up the almost perpendicular bank, 300 feet high, close to Hennepin's "three mountains." It was used in very early days, probably before the American Revolution, for raising and lowering heavy goods between the vessels and the portage wagons, and consisted of a flat car, on broad runners, moving on wooden rails. It was raised and lowered by a windlass, and this latter was operated by Indian labour then accessible only at the Indians' own price. Braves who ordinarily would scorn to work at any manual labour, gladly toiled all day for a plug of tobacco and a pint of whiskey. The tramway was notable as being the first known adaptation of the crude principle of a railroad in the United States.

It may not be amiss to mention also, the reservation of the Tuscarora Indians, east of Lewiston, where the half-breed remnants of the last-embraced tribe of the Six Nations now reside, cultivating their fields, and educating their children under the care of the State. A tribute also is due to Canadian foresight in the building of the Welland Canal which connects Canada's frontage on the Great Lakes with her system of St. Lawrence canals to the seaboard. Mention, finally, should be made of the modern suggestion of a ship railway around the Falls, touching, at its terminals, about the same points on the upper and lower river as those held in view in the previously-suggested ship canal, and proposing, in the ascent and descent of the Lewiston mountain (which was the old shore of Lake Ontario before it receded to its present level), as remarkable a triumph of engineering skill as was shown in the enormous projected locks and one hundred-acre basin of the ship canal.

Next, glance back to the many Indian villages which, long years ago, dotted the region, the four or more of the Neuter nation, or Kahkwas, on the eastern side of the river, and a much larger number on the western side; later on, to the gradual occupation of these lands by the Senecas, almost three generations after their ancestors had annihilated the Neuters; then, to the Seneca village, built on the site of the present city of Buffalo, and then to the one built years ago on the site of the village still called Tonawanda, where, of late years, at the "long house," was annually held the council of the remnants of the Six Nations; and then at the docks in that village where once floated the Indian's canoe, and where now is seen the maze of vessels whose cargoes have, in the last two decades, built up the commercial trade of this, the second largest lumber market in America.

Turn, next, to the geological page and recall the ever fresh and still much-discussed question as to the ages that it has taken the Falls to cut their way back from Lewiston to their present location; consider, too, the question regarding the time when a great inland sea covered the whole region, of which proof is, even to-day, found in the shells which underlie the soil on Goat Island and the adjacent country. Consider, further, the query as to when and why the great flood of waters abandoned its old channel which ran westward from the whirlpool to the edge of the bluff at St. Davids, far to the west of the present outlet of the river into Lake Ontario, and how that old channel, still easily traceable, was